CASE: SM-190
DATE: 10/01/10

FIRST SOLAR, INC. IN 2010

We're not competing against other PV companies…we're competing against the entire electricity generation market.

—Bruce Sohn, President of First Solar

INTRODUCTION

Sitting in his office in Tempe, Arizona, Bruce Sohn reflected on his three-year tenure as president of First Solar, and on the remarkable achievements of the exceptional people he had worked with for the past seven years. First Solar had been in operation for only 10 years, but had managed to cross the 1 gigawatt threshold in terms of annual solar module production capacity and to achieve a sub $1.00 cost per watt of electricity—the lowest in the industry. At the same time, the company had grown from a venture-backed start-up to the industry leader with over 5,200 associates, $2.1 billion in revenues and profit exceeding $640 million in 2009.[1] First Solar's low cost cadmium telluride (CdTe) thin-film technology was the leading choice for many photovoltaic installations across the world, and the company was now ramping up additional capacity to serve what was believed to be a growing market. The company's accomplishments had indeed been impressive, and Sohn noted with amusement that it was all predicated on the same sunlight that made the Phoenix area nearly uninhabitable during the middle of a summer

[1] First Solar form 10-K filed 2/22/2010.

Morgan Jerome Hallmon, Robert Siegel and Professor Robert A. Burgelman prepared this case as the basis for class discussion rather than to illustrate either effective or ineffective handling of an administrative situation.

day. (See **Exhibit 1** for First Solar Executive Bios.) However, the economic outlook for the entire photovoltaic industry, including First Solar, had changed drastically during the past year. First, the global financial crisis put pressure on the budgets of governments in Western Europe, the world's largest solar market. In fact, 2009 marked the first ever decrease in installed capacity year-over-year. In addition, the weak financial positions of many banks significantly reduced the attractiveness of tax equity, which had funded the majority of large solar development projects. Furthermore, module supply was anticipated to again outstrip demand in 2010, ensuring lower prices for First Solar's modules. Finally, crystalline silicon (c-Si) prices had dropped precipitously in response to overproduction, substantially reducing the Levelized Cost of Electricity (LCOE)[2] differential between c-Si and First Solar's thin film modules.

Unfortunately, the current dynamics would not allow Sohn to simply sit back and enjoy his company's well-earned success. Instead, he would have to help position the company to face its biggest challenges yet. In particular, was it possible for First Solar to compete in the energy business on a sustainable basis without the benefit of subsidies? How would the company make this transition and what business model would be necessary to do so? Did the company have the financial wherewithal to weather the current credit crisis while still pursuing strategically important projects? Was it possible to achieve the company's 30 percent market share target by 2015, and what implications would such growth have for the organization? Was it possible to maintain First Solar's unique culture at this pace? Would First Solar's core CdTe technology have enough life in it to stay ahead of the competition? Finally, what could First Solar do to eventually make PV solar cost competitive with conventional generation?

THE PHOTOVOLTAICS INDUSTRY

Early Evolution of the Solar Industry

The first photovoltaic (PV) device was made by Charles Fritts in 1883 when he melted selenium into a thin sheet on a metal substrate and pressed a gold-leaf film as the top contact. Foreseeing the future of solar power more than a century away, Fritts noted, "The current, if not wanted immediately, can be either stored where produced, in storage batteries … or transmitted at a distance and there used."[3] In 1954, Bell Labs in the U.S. serendipitously discovered the precursor to the modern solar cell when researchers noticed that semiconductor wafer diodes generated a voltage when exposed to light. These first solar cells were extremely low in conversion efficiency and therefore expensive to produce. Thus, early applications were limited

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[2] Levelized Cost of Electricity refers to the fully amortized cost of producing a unit of electricity. It takes into account the solar resource, system cost/watt, module lifetime and other parameters to compute an average $/kwh figure.

[3] C. Fritts, *Proceedings of the American Association for the Advancement of Science, Thirty-Third Meeting, Held at Philadelphia, Penn. September 1884," p.104.* (Salem: 1885)

to satellites and the space program, where costs were not a consideration and other energy sources did not exist.

In the 1980s, initial manufacturing facilities for producing photovoltaic modules from silicon p-n junction solar cells were built in the U.S., Japan and Europe by large semiconductor companies (see **Appendix 1** for a glossary of terms). Companies soon realized that the largest hurdle to the wide-scale adoption of solar power was the difficulty in scaling up the devices to commercially viable volumes while achieving acceptable device efficiencies.[4] In the U.S., most large semiconductor companies gave up their solar research and development efforts for this reason.

The first applications for widespread use of photovoltaic cells were small-scale, low-power consumer devices, such as calculators in the 1980s. Other novel applications of solar cells included outdoor lighting and rural electrification.[5] As small-scale devices using solar cells became more commonplace, utilities in developed countries began to investigate the technology's potential.

The use of photovoltaics in large-scale power generation did not occur until the mid 1980s when utilities began building photovoltaic plants to evaluate their suitability for two particular uses: 1) peak-load reduction, providing additional power to meet peak demand in the afternoon, and 2) as distributed generators, to reduce transmission and distribution losses. It was then that the modern era of photovoltaic power was ushered in.

Current Market for Solar Power

As of 2009, solar power was the world's fastest-growing energy technology.[6] Demand for PV production had been doubling globally every two years, growing by an average of 48 percent annually since 2002.[7] With an anticipated annual growth rate of 27 percent through 2012, the market was expected to moderate only slightly going forward.[8] PV panels generated electricity and either interconnected with utilities' power lines or acted as stand-alone generation for small facilities; over 90 percent of installed PV generating capacity worldwide consisted of grid-tied electrical systems.

Worldwide demand for solar power was driven by energy prices and, more often, by government policies. Solar energy often satisfied peak power needs as it produced power during the high-

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[4] A. Luque and Steven Hegedus, *Handbook of Photovoltaic Science and Engineering* (Hoboken, NJ: Wiley, 2003).
[5] Ibid.
[6] Adapted from Nanosolar 2009 Case Study.
[7] "Solar Expected to Maintain Its Status as the World's Fastest-Growing Energy Technology," SocialFunds.com, March 3, 2009.
[8] First Solar Corporate Overview presentation, March 1, 2010.

demand hours of the afternoon and was nearly at cost parity with flexible capacity "peaker" plants otherwise used to serve this load. The case for solar more broadly, however, would face hurdles until it became more cost competitive. The low rates of efficiency of solar cells, steep required investments in production, and high cost of component materials used to manufacture solar cells contributed to this problem. Solar prices had declined over time, however. In 1976, solar power cost approximately $2.00 per kilowatt-hour, but by 2010, prices per kilowatt-hour averaged between $0.15 and $0.40.[9] Regardless, prices were still too high to make solar energy broadly available without the aid of subsidies. While the price of solar electricity was heavily dependent on location, in general, the cost of solar far exceeded the cost of other sources of electricity, particularly fossil fuels, by multiples of three to eight times. (See **Exhibit 2** for a description of costs of various energy sources.)

Feed-In Tariffs

Several governments across the world instituted feed-in tariffs (FIT) to make solar power more economically attractive for their nations. The FITs were an incentive structure to encourage the use and development of alternative energies. Utilities were required to buy renewable power (solar, wind, etc.) at government-mandated above-market rates. The actual tariff imposed typically varied depending on the type of project (ground vs. roof installation) and usually continued for 15 to 20 years, decreasing over time as solar power became more economical to produce.[10] The tariff was typically paid for by all users of electricity through a small surcharge on utility bills. Feed-in tariffs provided perhaps the strongest regulatory framework for the growth of the solar industry, as power producers were guaranteed both a fixed price for their generation assets and, often just as important, access to the utility grid. Despite their effectiveness, however, FITs were not used in all markets.

Germany was clearly the leader in FITs, but Spain and Italy also aggressively used FITs to provide incentives for investors and developers. In 2008 Spain had one of the highest solar installation rates in Europe and had FITs to provide incentives. However, the country's FIT program was capped at 500 megawatts (MW) in 2009. By 2010 France, Italy, Greece and a number of other EU countries had also developed robust feed-in tariff structures, and were beginning to see growth catalyzed in their respective markets.[11]

Capital Subsidies

The U.S. introduced a 30 percent capital subsidy for renewable power producers through the Investment Tax Credit (ITC) in an effort to stimulate its nascent solar market. In practice, the ITC did not promote the installation of solar cells as anticipated. To receive the ITC capital subsidy, a company had to have sufficient taxable profits to offset. To date, this profitability

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[9] Adapted from Nanosolar 2009 Case Study.

[10] M. Mendonça, *Feed-In Tariffs: Accelerating the Deployment of Renewable Energy* (London: EarthScan, 2007).

[11] "Global Solar Power," HSBC Global Research, September 2009.

requirement had prevented many solar power players from taking advantage of the incentive. For this reason, the ITC had proven ineffective in catalyzing U.S. development of solar power. Changes to the ITC in 2010 extended the subsidy to utilities. With their strong balance sheets, consistent profitability and interest in achieving state mandated Renewable Portfolio Standards (RPS) targets, utilities were more likely to take advantage of such subsidies.

Recently the introduction of treasury grants alleviated the profitability requirement of the ITC, in that companies could opt to receive cash grants from the Treasury in lieu of the ITC. As another incentive, the Department of Energy (DOE) offered loan guarantees of U.S. $6 billion specifically for the production of solar energy plants in the U.S.[12]

Renewable Portfolio Standards

A final form of regulatory support for the solar industry existed in the form of government mandated standards. In the U.S., 11 states had already adopted Renewable Portfolio Standards (RPS), which required utilities to procure a prescribed amount of generation from clean sources. Most of these standards also included a specific target (a "carve out") for the proportion of power that must come from photovoltaics. RPSs varied by state in their effectiveness as some imposed actual fines and penalties for not meeting targets while others simply served as strong recommendations for the utilities.[13] Collectively, RPS targets were set such that roughly 20 percent of electrical power would be generated from renewable sources by 2020.

Power Purchase Agreements (PPAs)

A Power Purchase Agreement (PPA) was a contract between an electricity generator (provider) and a power purchaser (host) for energy, capacity and/or ancillary services. Such agreements played a key role in the financing of electricity-generating assets not owned by a utility. The seller under the PPA was typically an independent power producer (IPP).

Under a PPA, the PPA provider secured funding for the project, maintained and monitored the energy production, and sold the electricity to the host at a contractual price for the duration of the agreement. The duration of a PPA was usually between 5 and 25 years.[14] In some agreements, the host had the option to purchase the generating equipment from the PPA provider at the end of the term, could renew the contract with different terms, or could request that the equipment be removed. The main advantage of the PPA model was that the PPA could be used to raise financing. This was possible because it defined the output of the generating assets and the credit of its associated revenue streams.

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[12] "EERE News: DOE Offers $535 Million Loan Guarantee to Solyndra, Inc.", Apps1.eere.energy.gov. 2009-03-20.
[13] MJ Beck Consulting, June 10, 2010.
http://mjbeck.emtoolbox.com/?page=Renewable_Portfolio_Standards.
[14] "Solar Power Purchase Agreements | Green Power Partnership | US EPA," U.S. Environmental Protection Agency, June 1, 2010, http://www.epa.gov/grnpower/buygp/solarpower.htm.

Virtually all utility-scale solar projects in the U.S. were sold under a PPA. Thus, the terms of this agreement essentially set the price for the module. In addition, the PPA was a somewhat complicated arrangement in that successful bidding for the contract required land, module, engineering and construction assets all to be identified at the time of the bid. This complexity made it difficult for module producers to catalyze industry growth on their own, leading some to downstream integrate to better bid for PPAs.

Grid Parity

Grid parity referred to PV generation achieving cost parity on a $/kWh basis with conventional generation. At such time, it would no longer be necessary to fund solar installations with subsidies, as sheer economic forces would provide the proper incentives. Two different grid parity points existed for PV generation: retail and wholesale. Because retail electricity rates included transmission, distribution, administration and other costs, they were often much higher than the wholesale rates at which utilities sold power to each other. Thus, the hurdle for solar on the retail side of the meter was a bit lower—rates as high as $0.24/kWh were not uncommon for certain usage tiers in California.[15] Were solar to achieve this level of cost competitiveness, retail customers would have an incentive to install PV systems for home use. Wholesale rates, often much lower than retail, presented a bigger hurdle. However, even here there were high demand periods in the day when solar could be cost competitive with peaker gas turbine generation. When this occurred, utilities had an incentive to buy solar energy from purely a cost reduction standpoint—not to mention the benefits from eliminating externalities such as toxic emissions, greenhouse gases and hazardous waste.

The Solar Value Chain

Silicon Feedstock and Wafers (Traditional Crystalline-Si Cells)

The first step in making crystalline silicon (c-Si) solar cells involved creating wafers from silicon feedstock. In a process nearly identical to that used in electronic semiconductor manufacturing, raw silica (often sand) was refined in a furnace and slowly made into ultra-pure, round ingots. These ingots were then further processed into thin circular wafers, upon which the solar cells would be built.[16] The two largest consumers of silicon wafers were the semiconductor industry and the solar industry, and as a result of both strong semiconductor sales and solar capacity growth in 2008, the price of c-Si increased by nearly 80 percent over the previous year, making cells built from these materials less cost competitive. As opportunistic c-Si producers entered the market, however, supply increased dramatically and the cost of c-Si cells saw significant reduction in 2010 (35 percent 45 percent vs. 2008 prices).[17]

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[15] "Pacific Gas & Electric Tariff Book," PG&E, 16 May 2010. http://www.pge.com/tariffs/ERS.SHTML#ERS.

[16] A. Luque and Steven Hegedus, *Handbook of Photovoltaic Science and Engineering,* (Hoboken, NJ: Wiley, 2003).

[17] "Global Solar Power," HSBC Global Research September 2009.

Thin Films

Thin film cells did not use crystalline silicon wafers as a starting material, but rather utilized a typically inexpensive substrate (glass or aluminum, for example), upon which thin layers of semiconducting material were deposited. Typically the substrate comprised only a small fraction of the total cell cost. In addition, the semiconductor materials were far cheaper than using crystalline silicon as only a minute amount was used to coat the substrate—often as little as 1-2 percent of the material used in a c-Si cell. A wide variety of material compositions were used to manufacture thin films for solar cells. Amorphous Silicon, Cadmium Telluride (CdTe), Copper Indium Gallium Selenide (CIGS) and even some organic polymers were used to produce thin film cells in 2010.[18] Supply of the majority of thin film materials remained unaffected at the beginning of 2010.

Cells/Modules

Solar cells were the raw photoconducting elements that made up a larger PV system. They consisted of a transparent top electrode and conducting back contact, and they generated a current when placed in light of the appropriate wavelength. Modules were simply orderly collections of cells that were electrically connected to one another and packaged so as to resist the elements.

System Integration/Installation

Cells and modules were of little use unless properly integrated into a complete system to deliver electricity. Systems integrators and installers performed this task. Bulk modules were purchased from manufacturers, and they were then integrated with "Balance of System" (BOS) components to generate power. The BOS included components such as inverters (to convert DC to AC current), wiring (to connect modules together), other power regulation circuitry, mechanical substructures, and labor—perhaps the most significant cost component. In addition, the balance of system included all of the engineering, permitting and construction (EPC) activities that were necessary to make an installation operational. Often, BOS costs could be as high as 50 percent of the overall PV system cost.[19]

Existing Business Models

While many players within the solar industry operated in only a single part of the value chain, there were others who experimented with varying levels of vertical integration. (See **Exhibit 3** for a list of the models employed by the major players in the space.) Players like Yingli and Trina had migrated upstream into ingot and wafer production, probably in an effort to maintain control over the price of these very volatile inputs. Other players such as SunPower moved downstream into delivering entire systems to utility and IPP customers. Integration potentially

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[18] A.Luque and Steven Hegedus, op. cit.
[19] Ibid.

allowed these companies to avoid paying a margin between value chain steps; however, gains from specialization and scale could be lost as a result. In addition, when interface costs—margins in this case—between value chain steps were low, integration did not yield as much benefit.

FIRST SOLAR

Brief Company History

Founded by "glass genius" Harold McMaster, First Solar began as a glass company, not as a photovoltaics manufacturer. McMaster began his career as a research physicist for Libbey-Owens-Ford Glass in Toledo, Ohio. There he created advanced techniques for tempering glass—compressing, heating and chemically treating glass to give it additional tensile strength. In addition to its strength, tempered glass shattered into small pieces when broken, making it a safer alternative to conventional glass. In 1948, McMaster founded Permaglass, which produced tempered glass for the automotive and consumer markets where safety benefits were the greatest. Permaglass rode the success of the automotive market to become one of the largest glass producers in the U.S. and eventually was merged with Detroit-based Guardian Industries in 1969 to create the world's third-largest glass company at the time.[20]

In 1984, McMaster applied his expertise in glass manufacturing to the solar industry, founding Glasstech Solar. He understood then that cost competitiveness would be critical to the acceptance of the technology. In addition, McMaster sought alternatives to the leading c-Si approach prevalent in the solar industry at the time. Specifically, McMaster believed that he could use a commodity glass substrate as the principal building block for a solar array and coat the substrate with a light converting material. McMaster's goal was to reduce the cost of Glasstech Solar's modules compared to the modules produced by other solar companies by avoiding the need for expensive bulk crystalline silicon. This first venture attempted to use amorphous silicon as the light converting element, but was unsuccessful, forcing the company to liquidate after six years of operation.

Undeterred by his experience at Glasstech Solar, McMaster raised an additional $15 million in 1990 to found Solar Cells, Inc.[21] This company continued to use glass as a substrate, but experimented with a new thin film material, Cadmium Telluride (CdTe). While CdTe was a more promising technology than amorphous silicon, research progress was painstaking slow. Several times McMaster himself had to infuse the company with cash to allow it to continue its efforts. Despite these challenges, the company was able to produce a commercially viable process for producing thin film cells with CdTe by 1993. By 1998, Solar Cells, Inc. had annual

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[20] "After Long Wait, McMaster to Join Hall of Fame," toledoblade.com, April 29, 2008.
[21] Edward O. Welles, "Going for BROKE," *Inc.*, vol. 20, no. 8, pp. 66-78, June 1998.

production capacity of roughly 20 megawatts.[22] In 1999, a controlling interest in the company was acquired by True North Partners, and the company was renamed First Solar, LLC.

Technology

The modern photovoltaic industry was divided into two camps technologically: those who believed in achieving the lowest cost through high-efficiency but high-cost cells, and those who believed that low-cost, moderate-efficiency solar cells were the way to reach this goal. First Solar's CdTe thin film technology placed it squarely in the latter camp. Instead of using high-cost ultrapure c-Si, First Solar used much cheaper commodity glass as a backing for its cells while coating them with only a small amount of expensive light-converting semiconductor material.

Cadmium Telluride (CdTe)

Cadmium Telluride had been used in photovoltaics research for more than 60 years. It was an attractive material because of its favorable bandgap of 1.5eV, which was well matched to the energy distribution of the solar spectrum. In addition, the material could be deposited on a number of substrates rather cheaply as opposed to the epitaxial matching required of monocrystalline silicon cells.

Early drawbacks of the technology, however, concerned the potential toxicity of CdTe and its low electrical conversion efficiency. Cadmium was extremely toxic, causing fever in acute exposures and various forms of cancer when exposure was chronic. Concerns about toxicity stalled residential placements of First Solar panels in the EU until the company promised to recycle the panels appropriately. More of a challenge for this technology was its low conversion efficiency—the percentage of solar energy that was converted into electricity by the cells. Initial cells achieved efficiencies of roughly 7 percent, far lower than the > 20 percent efficiency achieved by c-Si cells. Subsequent improvements in design and manufacturing processes, however, allowed these cells to achieve roughly 16.5 percent efficiencies under optimal operating conditions.[23]

By 2009, First Solar's cells had an average conversion efficiency of roughly 11.1 percent. According to David Eaglesham, vice president of technology, with minor changes to the current process, the company could realistically get to a conversion efficiency of 12 percent and perhaps as high as a 14 percent conversion efficiency by 2014. Short-term efficiency gains were expected to come from increasing light transmission into the existing device. Future developments in optics, device contacts, grain-boundary engineering, bandgap tuning, and doping promised to

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[22] Ibid.

[23] NREL compilation of best research solar cell efficiencies. Compiled by Lawrence Kazmerski, National Renewable Energy Laboratory (NREL).

take cell efficiencies even higher, perhaps surpassing the 16.5 percent threshold achieved under optimal operating conditions and closer to the 18 percent theoretical limit for the device. (See **Exhibit 4** for improvement roadmap for CdTe cell.)

Evaluation of CdTe as Module Technology

The choice of CdTe by McMaster for First Solar's modules was no accident. The technology possessed a number of inherent characteristics that made it well suited for large-scale photovoltaic deployment. In particular, when VP of Technology Eaglesham evaluated any new technology within the solar industry, it had to perform well on four different criteria: 1) low cost/watt at the module level, 2) low cost/watt installed at the system level, 3) low Capex/watt of manufacturing capacity, and 4) fast energy payback time (EPBT). CdTe currently outperformed all other technologies in these respects.[24]

The first two of the company's criteria focused primarily on the cost effectiveness of electricity production from a particular technology. To perform well on this dimension, the technology had to achieve good conversion efficiency at low cost. While CdTe only achieved moderate efficiency—far better than that for organics, but below the efficiency of CIGS or c-Si cells (see **Exhibit 5** for a comparison of PV technology efficiencies)—its costs were significantly lower than most other technologies for a variety of reasons. First, the bill of materials was cheaper for CdTe, as glass, cadmium and tellurium were the principal inputs. Crystalline silicon was much more expensive to produce due to the purification process required, and CIGS cells used so many more layers (copper, indium, gallium, selenium, glass, and sometimes cadmium) that their materials costs were also inherently higher.

The simplicity of CdTe chemistry allowed its capital costs per watt of production to be substantially lower than that for competing technologies. CdTe was a binary compound formed by simply subliming cadmium and tellurium into a gas. Most of the processing could also be done at moderate temperature and pressure, reducing the amount of equipment necessary for fabrication. C-Si and CIGS solar cells, in contrast, were much more capital intensive to produce. As Eaglesham explained, "With crystalline silicon you spend most of your money getting high purity, and then with CIGS you spend most of your money on getting process control on each of the layers in the device in order to reduce device variability." Eaglesham further explained the often ignored importance of Capex per watt in the solar business:

> A lot of people from the semiconductor business come into PV assuming that if you drive down cost with large capital investments it's always OK. Even in the semiconductor business this meant that the cost of the fab was so much that there

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[24] As of Q1 2010, First Solar cells boasted a module cost/watt of <\$0.84, a system cost/watt of roughly \$2.17, a Capex/watt of <\$0.80, and an energy payback time of roughly 0.8 years.

> was no real net cash coming out of the business. Now you simply can't do that in the solar business because the pace of growth in the industry is so fast and the growth area is so large. People with high capital cost positions struggle to find the capital for the next round of expansion.[25]

The low Capex per watt that First Solar achieved with CdTe enabled the company to scale faster (or at least more cheaply) than its competitors. The company was able to fund the bulk of its growth through cash flow from operations, while competitors had all grown through leverage. As Eaglesham noted, "[Capex] is the magic of Cad-Tel if you like, because right now it costs less than a dollar a watt to make. We sell it for a number that's much higher than that, and we throw off all this cash in operations … to make the capital investments for the next factory."

The final criterion, energy payback time (EPBT) was a measure of how quickly the energy content used to manufacture the cell was recovered through device operation. It also served as a proxy for the carbon footprint of the cell. This criterion, while not yet a customer purchase consideration, was nonetheless monumentally important as solar was a green technology. The simpler chemistry and device processing required to fabricate CdTe cells allowed First Solar to achieve an industry leading EPBT of approximately nine months.

Manufacturing

While the initial choice of technology played a major role in the ultimate cost/watt for the resulting solar cell, the importance of manufacturing costs could not be overlooked. The proprietary glass substrate and CdTe thin film stack placed bounds on the raw materials costs for First Solar's cells. However, manufacturing efficiencies went a long way in making the company a cost leader. In particular, the high throughput vapor deposition process used by the company allowed naked planes of glass to emerge from the line as solar cells in only a few hours. The company also used a continuous flow process to further increase throughput. Furthermore, the shifting of manufacturing capacity to lower-cost countries was expected to have a major impact on the cost/watt for First Solar modules.[26]

First Solar began manufacturing in its original Perrysburg, Ohio plant. When production capacity first came online in 2005, the plant and company as a whole was capable of producing 25MW annually. By mid-2010, the company now had six manufacturing locations spanning North America, Asia, and Europe. These sites provided 24 production lines with a combined capacity of 1.4GW. This extraordinary growth in manufacturing capacity was the result of industry-leading factory ramps and constant throughput improvements on existing lines. Both of these

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[25] All quotes are taken from case writer interviews unless otherwise noted.

[26] First Solar Analyst/Investor Meeting Presentation, Las Vegas, June 24, 2009.

factors were consequences of the company's "Copy Smart" manufacturing philosophy. Borrowed from the Intel mantra of "Copy Exactly!," Copy Smart attempted to build and run new manufacturing facilities in an identical fashion. By standardizing site design, layout, equipment and other production parameters, factories could be ramped at exceptional speeds without suffering degradation in product quality. Copy Smart also allowed best practices to be shared quickly across factories, yielding continuous improvements in throughput.

The testament to First Solar's prowess in manufacturing was the industry-leading cost per watt that the company had achieved. First Solar had gone from a cost of $1.29/W at beginning of 2007 to $0.84/W at year's end 2009. Nearly 50 percent of this cost improvement was believed to have come from manufacturing efficiencies (see **Exhibit 6** for system cost per watt trend).

Market Strategy

For nearly its entire first decade of operation, First Solar had relied upon markets with large existing subsidies for the sale of its modules. As solar had not been cost competitive with conventional generation, subsidies were the only way to encourage investment in the technology. As a result, countries such as Germany, Spain and France had emerged as leading solar markets because of their respective governments' commitment to solar power.[27]

TK Kallenbach, EVP of marketing and product management, further explained the development of subsidy markets:

> We were really fortunate that Germany was committed to this type of resource. And it was willing to put its money where its mouth was and say that it was going to create this subsidy so that [solar would be] economically viable in Germany, where you don't have the solar resource that you'd like to get this whole thing started.

While the company's roots lay in the subsidy markets of Western Europe, First Solar's longer-term plan had always been to shift towards what the company referred to as "transition" and "sustainable" markets in which economic fundamentals supported PV solar demand. Subsidy markets were key to this shift, however, as they provided the experience curve learnings that had allowed First Solar and others to rapidly reduce solar costs, increasing their competitiveness relative to conventional generation. As Kallenbach remarked, "[Germany] was kind of a big thing for us because when we started to scale up, the costs really dropped fast."

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[27] "Development of Renewable Energy Sources in Germany 2009," Federal Ministry for Environment, Nature Conservation and Nuclear Safety (April 26, 2010).

In 2009, First Solar began to speak openly about its intentions to pursue transition and sustainable markets, providing loose definitions for these two environments. Transition markets were those in which a light subsidy (such as the ITC in the U.S.), combined with otherwise favorable conditions for solar generation, made PV solar costs competitive with peak load and other high cost applications. Sustainable markets were those which required no subsidy and in which conditions were favorable enough to make PV solar costs competitive with conventional generation. This strategy was in stark contrast to that of many competitors within the industry who sought to expand nearly exclusively through growth within existing subsidy markets. First Solar's superior cost position, however, allowed it to access markets with lower price points than anyone else in the industry.

According to Kallenbach, areas in which market forces would support solar had to score well on four principal dimensions. First, the area had to have high annual insolation (good solar resource) as this increased the system energy yield, all else being equal. Second, high electricity prices were favorable as they reduced the cost hurdle for substitution by PV. Third, the area needed to be in close proximity to a large load to maximize the amount of generation sold. Finally, ready access to development land was required to support the building of solar facilities. Using these criteria, many of the subsidy markets of Western Europe were unattractive from a long-term sustainability standpoint (see **Exhibit 7** for worldwide insolation and electricity prices). Thus, executing on the transition and sustainable market strategy would require First Solar to enter a dramatically different set of markets than it had experienced in the past.

Business Model

First Solar's business model evolved substantially over the course of its history. The company began its existence as a pure play cell and module manufacturer. As discussed previously, focusing on a narrow value chain step provided the company with benefits of specialization and scale. Due to its industry-leading cost per watt and the supply constrained environment in which early solar players operated, First Solar was able to sell all of its capacity (for many years in advance) to hungry systems integrators, primarily in Europe. The well-developed European ecosystem of developers and systems integrators made the cell and module production business model a viable one for First Solar.

Cell and module costs were only part of the equation in terms of overall system cost. Other components, such as inverters, wiring, and most notably labor and construction, called the Balance of System (BOS), constituted roughly 50 percent of the costs of a PV installation. Thus, a competitor with worse module economics could still potentially achieve a similar total system cost to that of First Solar if it used a more competitive systems integrator with a lower BOS. This dynamic was particularly important in markets like those of the U.S., where a well-developed systems integrator/developer ecosystem did not exist and where there was extremely high variability in BOS costs. In late 2007, First Solar purchased systems integrator Turner

Renewable Energy for $34.3 million in cash and stock, which partially mitigated this problem.[28] The purchase gave First Solar more control over the entire system cost when selling to IPP and utility customers.

Vertical Integration to Enter U.S. Market

While control over the total cost/watt installed was certainly a major motivation for First Solar's acquisition of Turner, the move downstream was really more about catalyzing the U.S. solar market. The U.S. market differed in many substantial ways from that of the EU and thus required a different entry strategy. First, the U.S. market was extremely concentrated, with large utility-scale projects driving the bulk of demand. In addition, the U.S. did not have a well-developed systems integration ecosystem, which made it difficult to reliably put together a bid for such large projects. Finally, the incentive in the U.S., the ITC, was far more complex than the simple feed-in tariff and required the combination of developer, Engineering Permitting and Construction (EPC), module supplier, and IPP to take advantage of it. The need to coordinate so many different activities to deliver the "complete product" demanded by the marketplace made integration a strategic imperative for First Solar.

Jim Lamon, vice president of systems engineering and construction, described the situation:

> It was very immature in North America's time for solar and certainly for what we call EPC. Some very astute individuals within the company decided to conduct market assessments for North America, and after discussing with utilities and IPPs, came to the conclusion that most of them wanted to acquire their solar power via EPC…. Who has expertise in installation? The answer's virtually no one with the exception of these small companies. Turner was one of those.

In early 2009, First Solar purchased financially troubled developer OptiSolar, for $400 million in stock. This downstream integrated the company further, as it was now in the solar plant development business. Through the OptiSolar acquisition, the company obtained a rich 1.3GW pipeline of projects in which First Solar could place its modules.[29] Shortly afterwards, in early 2010, the company purchased development projects from Edison Mission. Most recently First Solar acquired NextLight and its 1.1 GW development pipeline in April 2010.[30] Participation in the development business further enhanced First Solar's ability to deliver the "complete product" for utility customers. As Sohn remarked, "American utilities had no interest in buying individual

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[28] "First Solar Buys Turner Renewable Energy," Cleantech Group, December 7, 2007 http://cleantech.com/news/2144/first-solar-buys-turner-renewable-energy

[29] "First Solar (FSLR) to Acquire OptiSolar's Solar Project Pipeline for $400M in Stock," StreetInsider.com., June 15, 2010.

[30] Frosty Wooldridge, "OfficialWire: Mergers & Acquisitions Deal Analysis First Solar to Acquire NextLight Renewable Power New Market Report Published," June 2, 2010, http://www.officialwire.com.

modules, although they were willing to buy millions of them if they were wrapped in a power plant." Finally, the development business locked up future market share as there were a limited number of large parcels of land suitable for profitable solar energy production.

Long-Term Competitive Advantage from Integration

Downstream integration could prove a sustainable competitive advantage for First Solar. Specifically, the EPC and development businesses provided higher margin sales channels for the company's modules, and they were more resistant to commoditization. In addition, the company gained relationships with IPPs and utilities as well as expertise in installation which could be leveraged in other markets. Thus, even if the U.S. solar market were to mature to the point that First Solar no longer needed to participate in development and EPC to drive volume growth, the company could still choose to do so to maintain profitability.

Lamon elaborated on the superior pricing through the EPC channel:

> [Currently] those who sell only modules have already been commoditized…. The size of the projects that we were doing in 2008 we don't bid on today simply because the scale of what we have available to us out there. We leave that to the smaller companies, and we know those module prices and we enjoy a much more robust margin when we do the development EPC ourselves…. As long as these power purchase agreements really set the price, and we're driving the cost down underneath that PPA.

Integration also eliminated double marginalization problems associated with JV relationships, common in the solar industry. As most participants in the solar industry operated in only one part of the value chain, they had to form joint ventures to compete within the utility-scale market. This structure inherently produced incentive misalignment as each organization sought to give up only enough margin to be competitive in the project bidding process.

First Solar's integrated model eliminated the conflict experienced by JVs, as true module and EPC costs were completely transparent. As Lamon remarked, "A cent per watt is a cent per watt whether it's on the BOS or module side … we add all of our margin at the bottom line." First Solar had to do more than simply create a vertical organization on paper to realize all of its benefits. In particular, it was the proper design of incentives which further aligned the interests of all employees. To achieve this, the company awarded bonuses to all associates based on the same metric—system cost/watt at the module level. As Lamon noted, "By putting [this] bonus system out there the company is telling the associates that that's the type of behavior that we want to encourage here; full and complete cooperation." U.S. competitor SunPower had also adopted a vertically integrated model. However, several observers noted that a very siloed

culture and department specific metrics had limited SunPower's ability to capitalize on the immense benefits of integration.

Perhaps as important as the pricing and system cost benefits of integration were the relationships with downstream customers that First Solar acquired, as well as the skills in EPC that could be leveraged in other markets. Participation in EPC allowed the company to sell directly to utility and IPP end customers, avoiding the loss of margin associated with selling through an intermediary. These relationships and the associated reputation for high-quality solar plant construction were likely to persist and provide value to First Solar, even if the module were to eventually become commoditized. In addition, EPC activities in the U.S. created positive spillovers in other markets. In particular, best practices created within the U.S. organization were shared with European systems integrators to help reduce their system cost per watt (allowing them to pay more for First Solar's modules or simply win a very competitive bid). Lamon recounted one recent example in which a labor-saving clip that had become standard within the U.S. was rolled out to a couple of European installers, creating higher margins for both First Solar and the installers. A clip fastens the solar module to the assembly beneath.

Financial Strategy

First Solar's financial performance had been impressive during its first few years of operation. In a few short years the company had increased its annual revenues and profits nearly four-fold. The company grew from a start-up to a leader in the solar space. Accordingly, the company's stock had returned significant value to shareholders. Debuting at roughly $25 per share in November 2007, the stock reached as high as $311 a share and traded at roughly $120 at the time of writing this case. (See **Exhibit 8** for company financial performance.) Successfully managing the company to this level of performance required not only a sound market strategy, but also a financial strategy that was aligned with the underlying drivers of growth of the business, while at the same time mitigating the significant volatility that existed in growing technology companies.

The first major financial decision that the company made was to avoid using substantial leverage to grow. Having witnessed the dangers of liberal debt use in an environment of significant volatility while in the semiconductor business, much of First Solar's senior management team sought to avoid this peril at the outset. Jens Meyerhoff, chief financial officer, explained, "We wanted this to be different from semiconductors … too much leverage is dangerous at an early stage. We started with a model that asked how much debt we could carry under a highly stressed business case and still maintain a good credit rating." These early prudent decisions produced the strongest balance sheet in the industry. The company boasted a single A rating on its corporate

debt and was the only net cash positive module producer, with a balance of $552 million at the end of Q1 2010.[31]

First Solar typically had two uses for the capital it raised: the expansion of manufacturing capacity or the financing of solar projects. In keeping with the philosophy of low leverage, capacity expansions were historically funded 50/50 through equity capital and cash flow from operations. Thus, the low capex/watt achieved by the CdTe technology had a direct impact on the company's financing needs as it allowed First Solar to continue to aggressively build out capacity despite cool equity markets. More recently, the most significant financing activities had been related to project development, construction and term financing—funding required by the growing systems business. Here the company chose to leverage its investment grade corporate rating to achieve substantially lower rates on the non-recourse debt issued at a project level.

Return on Net Assets (RONA) was the metric CFO Meyerhoff used to measure the financial performance of the company as it captured both P&L performance and capital efficiency. He further explained:

> I look at my business as having four cost columns that must be managed: the module, EPC, development costs, and the WACC. We have intentionally under-levered at the corporate level, which means that my WACC[32] is higher than it needs to be there. However, I get a much better WACC as a result for my projects. Then I can drive up my corporate asset turnover through more module sales and my margins increase because I don't have to pay as much for debt. Overall, I get a much better RONA[33] this way than by lowering the corporate WACC.

Implicit in this statement was the strategic recognition that the availability of project financing presented a significant constraint to the overall industry. Meyerhoff had chosen to focus on removing this constraint by serving as a credit for major solar projects instead of exclusively optimizing its module manufacturing operations as pure-play competitors had done. Thus, while First Solar paid more for capacity expansions and other capital expenditures because it chose to eschew leverage, its project partners paid far less for financing as a result of the company's strong balance sheet. These projects, in turn, drove First Solar's module placements and allowed the company to achieve an industry-leading RONA. Given the company's position as the sole credit for the U.S. EPC business, Meyerhoff's strategy had the potential to increase in salience as the systems division continued to grow in size.

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[31] First Solar SEC Form 10-Q filed April 29, 2010.
[32] Weighted Average Cost of Capital.
[33] Return on Net Assets net income as a percentage of total assets minus total liabilities.

Going forward, Meyerhoff believed the company would continue to improve both the corporate and project credit ratings, with a goal of having investment grade project debt by year end 2010. Such a rating would ensure the profitable growth of the systems business. In addition to this, the company hoped to engage more strategic utility investors in future project financings as opposed to simply going with the best term sheet. Strategic investors often brought more assets in the form of regulatory relationships, domain expertise and a commitment to solar power that financial investors often lacked. Finally, Meyerhoff planned to continue to educate Wall Street on how to measure the company's performance with RONA as opposed to gross margin. He wondered, however, if technology investors would ever adopt this practice or whether the holding of the stock would simply trend away from this group.

Customers

Given the rich subsidies in the European market, it should come as no surprise that the majority of placements and customers were located there. According to the company's 2009 10-K, First Solar's largest seven systems integration customers in Europe were responsible for greater than 90 percent of its revenues.[34] Germany and Spain were historically the largest two markets for the company's products, though recent events had mitigated their importance somewhat. Systems integrators in these countries maintained relationships with residential, commercial, and utility consumers of solar energy, obviating the need for First Solar to perform any of these activities.

First Solar's largest customers in the U.S. were initially also systems integrators. However, the U.S. market was far more fragmented than that of Europe. In addition, solar energy adoption had been slower in America. Residential customers using net metering and ITCs were the first group to really seize upon solar power as an alternative in the U.S. due to the lower cost hurdle associated with retail electricity prices.[35] Thus, First Solar invested $25 million in residential installer Solar City to understand how to compete in the retail market. However, it was clear that utility-scale PV projects were the future direction of the U.S. market, and First Solar acquired Turner and OptiSolar to gain access to these customers directly. By 2010, its largest U.S. customers included utilities and IPPs such as Sempra, PG&E, and Southern California Edison.[36]

Sustainability

The entire renewable energy industry was differentiated by the fact that it sought to be both clean and sustainable. Indeed, First Solar's mission statement read, "To create enduring value by

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[34] First Solar Form 10-K filed 2/22/2010.

[35] Michael Balchunas, "Arizona Utility Seeks Reduction in Rebate as Solar PV Takes Off," Sunpluggers.com: *The Solar Home & Business Journal*, June 23, 2010.

[36] Company website.

enabling a world powered by clean, affordable solar electricity."[37] Achieving the lowest cost/watt or the industry-leading Capex/watt had little significance if the central mandate for renewable technology was not accomplished. First Solar had accordingly devoted considerable resources to ensuring that its devices were both clean and sustainable. It created a Sustainable Development group within the organization to continuously assess the environmental impact of the company's products. In addition, First Solar invested in a module recycling program, putting aside a portion of each sale to provide for the reclamation of modules at end-of-life.

First Solar used Life Cycle Analysis (LCA) to evaluate the environmental impact of its modules. The energy and material inputs were calculated for the entire supply chain: processing, manufacturing, use, disposal and recycling stages of the device's existence. In addition, effluents and other environmentally harmful outputs were computed for each step.

While LCA provided a very good qualitative picture of device impacts, direct comparisons with other technologies were performed using better-known carbon footprint and Energy Payback Time (EPBT) metrics. Company and external analysis concluded that CdTe cells exhibited the best sustainability characteristics amongst PV technologies. The energy intensive refining and purification processes associated with c-Si cells decreased their relative sustainability, while the increased supply chain complexity (more raw materials to refine) and numerous processing steps caused the relative sustainability of CIGS to suffer. However, as First Solar's vice president of sustainable development, Lisa Krueger, remarked, "The real thing to notice with renewable is not necessarily how they stack up against each other, but rather that they are all orders of magnitude better than the use of fossil fuels." Indeed, c-Si PV, CdTe PV and wind power were all 50-100x better from a carbon footprint perspective than using either coal or oil generation. (See **Exhibit 9** for an analysis of the CO2 footprints of generation technologies.)

Although sustainability was not yet an acceptance criteria for customers at that time, Krueger's Sustainable Development organization hoped to keep it on the radar such that it might one day be a critical consideration. Her group met often with science and other government agencies to educate them on LCA. In time, it was conceivable that regulators would begin to place restrictions on the types of modules that could be used in installations based on their sustainability characteristics.

MAJOR CHALLENGES

First Solar's initial decade in operation had been extremely successful; however, the future presented significant challenges to the company on a variety of fronts. Most immediate was the global financial crisis, which had severely impacted the budgets of many of the subsidy-

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[37] First Solar Annual Report 2009.

providing countries. As a result, imminent caps on the purchase of subsidized power and reductions in feed-in tariff rates hastened the race towards grid parity. Indeed, 2009 marked the first annual decline in demand since the inception of the PV industry. The financial crisis also decimated the project financing landscape, making access to capital for future installations far more difficult to obtain. In addition, the high profitability and rapid growth of solar over the previous decade had intensified competition in the space from established players and upstarts alike. Furthermore, cost reductions achieved by c-Si players and novel thin film producers with fundamentally different efficiency limits put pressure on First Solar's core technology. Perhaps the biggest challenge to First Solar and the entire photovoltaics industry, however, was in removing the cost and technical hurdles that currently prevented solar power from ever comprising a meaningful portion of the world's energy needs.

Changes Within Subsidy Markets

The fact that the solar industry experienced its first year over year decline in 2009 was, no doubt, a consequence of the global financial crisis which crippled public spending in most EU localities. (See **Exhibit 10** for solar module demand from 2008 to 2012 in select countries.) Most countries responded to the stresses on their budgets by either placing a cap on the amount of power that could be "fed-in" or reducing the tariff rate. Until solar achieved grid parity, these subsidies would be vitally important to overall market growth.

Germany

The feed-in tariff (EEG)[38] had been the primary driver of growth within Germany's solar industry despite the country's rather poor insolation. Perhaps anticipating future overcapacity in the sector, parliament amended the tariff in 2007 to increase the degression rate per year from 5 percent to 8-10 percent, starting in 2009. Thus, the 2010 tariff in Germany would range between €0.29 and €0.40, limiting the market to a slightly smaller field of players efficient enough to earn a profit at this pricing level.[39]

Spain

Citing that Solar power had become unsustainable within the country—actual capacity in 2008 being four times the target for 2010—the Spanish government decided to cut the cap for subsidized solar power from 1,200MW in 2008 to only 500MW in 2009. Two-thirds of this capacity would go to roof-mounted installations and the rest to installations on the ground. The 2010 cap had been set even lower at 460MW. In addition, the tariff was significantly reduced from EUR 0.45/kWh in 2008 to between €0.32 to €0.34/kWh in 2009. The imposition of this cap

[38] Erneuerbare-Energien-Gesetz—see Glossary of Terms.
[39] "Global Solar Power," HSBC Global Research September 2009.

and the approximately 30 percent reduction in tariff significantly decreased the attractiveness of what had been the world's third-largest solar market.[40]

Italy

With some of the best insolation in all of Europe and nearly 1.1GW of untapped feed-in capacity, Italy promised to balk the EU trend, serving as a major area of growth in 2010. The rates were also some of the best in Europe at roughly €0.36 to €0.44/kWh depending on system type.[41]

United States

While the U.S. had yet to offer a full-blown feed-in tariff, it did encourage solar development through the Investment Tax Credit (ITC), DOE loan guarantees, and treasury grants. Congress voted in 2008 to extend the ITC for an additional eight years, which would provide a 30 percent subsidy on all capital investment in solar manufacturing and producing facilities. The extension of the tax credit, combined with nearing RPS targets in 11 states, made the U.S. a very attractive market going forward.[42] However, the complexity of the subsidy vehicle limited the market to primarily utility-scale projects and those few players with sufficient access to credit, scale and engineering capability to build large solar installations.

China

China represented a potential bright spot for the industry in 2010. It would continue with the RMB 20/W capital subsidy that the Ministry of Finance approved in March 2009. There was currently no limit to the subsidy and all installations greater than 50kW were eligible subject to various efficiency criteria, which varied by core cell/module technology. The Chinese government also approved the "Golden Sun" program aimed at creating solar IPPs within China. That program reimbursed 50 percent of all capital spending on PV installations of 500MW or more; 70 percent of capital spending was reimbursed for installations in regions without access to grid electricity.

Whether China would truly be an opportunity for the *entire* solar industry remained unclear despite strong subsidies. With its history of preferential policies and non-transparent business practices, the Chinese market would not necessarily be a level playing field for all competitors. The government's strongly stated commitment to leadership within PV solar made a truly open market even less probable. Indeed, China's wind industry provided a glimpse of what solar companies could potentially expect. China had virtually no domestic wind industry as of 2004, but through closed concession bidding Chinese firms managed to capture 56 percent of the

[40] Ibid.
[41] Ibid.
[42] Ibid.

market in 2007 and roughly 85 percent in 2010,[43] despite technology inferior to that of worldwide leaders Vestas, Gamesa, Suzlon and GE.[44]

Challenging Project Finance Environment

A serious consequence of the global financial crisis of 2008 was that the market for project finance virtually evaporated overnight. Given that a significant portion of the company's profits and revenues were derived from the systems business, which relied heavily on project finance, the general decline in the debt markets could have a substantial impact on future financial performance. As CFO Jens Meyerhoff noted, "We have a 2.2 GW pipeline in the U.S., which translates into a $6 billion to $7 billion financing need on the project side…. In Europe you're talking about an annual … €18 billion to €20 billion per year."

First Solar averted misfortune in 2008 by spotting and managing the credit crisis early. Meyerhoff explained, "We learned of [the credit crisis], I would say, six weeks before the broader masses … which [was] very important because we started to talk to all of the development banks in Europe." This good fortune worked for the company in the past, but could obviously not be relied upon to solve the more general malaise in the credit markets and tax equity markets that existed going forward. Although the EU project financing environment was showing signs of health, the U.S. market was still in shambles in 2010, yet First Solar's financing needs remained unchanged. Surely, the company's strong capitalization, cash flow from operations and its investment grade corporate debt would help it to weather the current storm, but eventually the business needed access to traditional levels of project financing to maintain its growth trajectory.

Increased Competition

With a 48 percent compound annual growth rate since 2002 and 50 percent gross margin, the solar industry had attracted a number of new companies, causing competition to intensify in the later part of the decade.[45] Moreover, the projected contraction of demand promised to further exacerbate competition in 2010. In addition, the entry of upstarts with radically different technologies threatened to potentially disrupt the market in the future. Finally, the strong commitment of the Chinese government to leadership in solar power ensured that competition from the Far East would continue to intensify. China's stunning recent development of a domestic wind industry in the span of only a couple of years had proven how formidable the nation could be when sufficiently motivated.

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[43] China Electricity Council press release, Electric Power Industry Statistics, http:\\www.cec.org.cn.

[44] Chen Limin, "China's Wind Energy Industry Sees Challenges," *China Daily* website Connecting China Connecting the World, July 14, 2010.

[45] "Price Drops Heat Up Solar Market Competition," *EETimes Asia*, March 1, 2010.

First Solar had a substantial lead over its competitors in terms of module cost/watt; however, the entire industry was still in its infancy with many opportunities for competitors to usurp the company's lead. The market was still very fragmented with no single competitor having dominant share (see **Exhibit 11** for industry market shares). Indeed, despite its cost advantage, First Solar only commanded roughly 13 percent of the market—though it was one of the few companies expected to gain share in 2010.

The vast majority of First Solar's competitors were exclusively module manufacturers. In this space, Suntech, Sharp, Yingli and German manufacturer QCells were the company's largest competition. In addition, upstarts such as Solyndra and Nanosolar represented potential future threats if their technology could achieve commercial scale.[46] Because the company participated more broadly in the energy market, it also had to expand its scope to now include threats from EPC providers and Developers such as Juwi Solar and others.

Suntech Power

Headquartered in Wuxi, China, Suntech Power was the world's largest producer of c-Si modules in 2010.[47] In its short nine-year history the company had managed to secure 7 percent of the worldwide solar market with 595MW of production capacity. More than half of Suntech's modules were placed in the EU and roughly 15 percent were deployed in China. The potential size of the market, however, made U.S. utility scale an attractive growth prospect for the company. As a result, Suntech had devoted significant resources towards building a U.S. manufacturing presence and building share of the market. A nearly 12 percent reduction in c-Si wafer prices between Q4 2009 and Q1 2010 continued to make Suntech's modules more cost competitive with those from First Solar. At the time of writing this case, the company was on track to triple its 2009 U.S. sales in 2010.[48]

Sharp Electronics

Leveraging decades of semiconductor expertise, Japanese manufacturer Sharp had the third-highest market share at year-end 2009 with an estimated annual production capacity of 580MW and 7 percent of the total market. While Sharp technically had a portfolio of products, its primary focus was on crystalline silicon cells. Sharp's solar technology was initially an offshoot of a legacy division producing cells for space and satellite applications in which high efficiency was absolutely critical (often at the expense of keeping costs down).[49] This heritage was evident in Sharp's current line of products which boasted some of the highest efficiencies in the industry.

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[46] Production capacity of under 100MW represents less than 1 percent of market. All noteworthy solar producers have crossed this threshold.
[47] Suntech Power Holdings Q1 2010 Earnings presentation.
[48] Ibid.
[49] A. Luque and Steven Hegedus, op. cit.

Indeed, the highest-efficiency non-concentrator solar cell produced as of mid-2010 was a Sharp triple junction cell that achieved a conversion efficiency of 35.8 percent.

Yingli Green Energy

Through its largest subsidiary, Yingli Solar, Yingli Green Energy had been producing polysilicon solar cells since 1998. The company had grown quickly, going from 50MW of capacity in 2004 to more than 600MW in 2010.[50] Shipments had grown even faster than capacity from a mere 6MW in 2004 to roughly 490MW at year end 2009 and 5 percent of the worldwide market. The company's exceptional growth reflected the commitment that China had made to leadership in the solar industry. In addition to its impressive growth, Yingli was an interesting player in that it had chosen to vertically integrate upstream into silicon refinement and wafer production through its Fine Silicon, Ltd. subsidiary. This move ensured Yingli would have access to 3000 MT of bulk silicon for its modules regardless of supply constraints within the broader market. It was likely an overreaction to the industry undersupply experienced in 2008, and it remained to be seen whether this move truly provided a competitive advantage for Yingli. Going forward, the company had set its sights on the U.S. market, having captured nearly one-third of the California solar market and with plans to build its next facility in either Phoenix or Austin.[51]

QCells

Founded in 1999, the German solar cell producer quickly grew to capture roughly 6 percent of the solar market by year end 2009. With an annual production capacity of roughly 540 MW, the company was one of the largest in the industry. The company's impressive growth trajectory was achieved largely through acquisitions, rather than organic growth. QCells' modules were not limited to a single technology, but instead the company had adopted a portfolio approach. Among its subsidiaries were Calyxo (CdTe), CSG Solar (Copper Selenium Gallium), Sovello (string ribbon), Flexcell (amorphous-Si), Solaria (c-Si), and Solibro (CIGS). Such technological diversification mitigated the company's technology risk, but also diverted managerial focus and manufacturing scale away from any single technology. By 2010, the company had also moved into project development for large customers through its QCI line of business. Despite its strong market position, QCells was unprofitable, losing roughly 15 percent on an EBIT basis in 2009.

Solyndra/Nanosolar

Solyndra and Nanosolar were two San Francisco Bay Area start-ups that represented potential technological disruptions within the industry. These two companies employed Copper Indium Gallium Selenide (CIGS) cells to convert light into electricity. While a clear tradeoff existed between the high efficiency, high cost of c-Si cells and the lower cost but lower efficiency of

[50] "Yingli Green Energy at a Glance," Corporate Fact Sheet, updated Feb 3, 2010.

[51] "From California, Chinese Solar Maker Looks East," *The New York Times*, March 3, 2010.

CdTe thin films, CIGS was an attempt to define a new point on the cost/quality frontier. Specifically, CIGS cells used thin films to reduce costs, but employed a more efficient semiconducting material, leading to average efficiencies of roughly 14.5 percent (maximum of 20 percent) as compared with an average of 11 percent for CdTe (maximum of 16.7 percent). Both companies utilized a continuous flow foil printing process to further reduce manufacturing costs. Solyndra had also innovated on the basic design of the solar cell by rolling its photoconducting foil into cylinders as opposed to flat sheets, yielding better performance in diffuse light.[52] As of 2010 neither company was yet producing modules at a commercially meaningful scale.

Applied Materials

Though not a direct competitor to First Solar, Santa Clara-based Applied Materials nonetheless had a major impact on the solar module business. Specifically, the company was able to apply capabilities developed during its 50-year history in the semiconductor tools and metrology business to the solar industry. As sales to the traditional semiconductor market continued to decline, Applied looked to solar as an avenue of growth. Introduced in 2007, the company's SunFab production line provided all of the tools and equipment to manufacture single or tandem junction silicon thin film solar cells. This move dramatically reduced the technology development hurdle for many companies seeking to enter the already crowded market, potentially accelerating commoditization of the module. The company continued its foray into solar equipment in 2008 by acquiring the Italian firm Baccini SpA, giving it access to core metallization technology used in c-Si cells.[53]

The development of SunFab may have been a bit premature, however, as basic process technology and, indeed, a dominant design were still very much in flux within the industry. This differed significantly from the very mature semiconductor market that Applied was most familiar with. Without significant process technology investment, it was unlikely that SunFab would continue to compete with more specialized leaders. The company's inability to sign significant customers to date was troubling. However, Applied was well capitalized enough to one day produce a sustainable process technology platform for the industry.

Juwi Solar

EPC providers and Developers such as Juwi were also not traditional competitors to First Solar. In Europe, First Solar was actually a Juwi customer, distributing its modules via the German company. Under such an arrangement, Juwi would bid for a power supply contract with a utility and then partner with First Solar to deliver the module component. Juwi offered utilities full

[52] Solyndra corporate website.

[53] "Applied Materials to Accelerate Its Solar Roadmap with Acquisition of Baccini," press release, November 29, 2007.

engineering, permitting, construction and O&M services as well as possessing development capabilities.[54]

First Solar's downstream integration into EPC and land development through the Turner, OptiSolar and NextLight acquisitions, however, brought it into even closer competition with system integration and development players. The company could now credibly bid for PPAs directly instead of alongside Juwi. The sheer possibility of such a move could encourage defensive upstream moves by Juwi and other EPC/Development players who already had strong ties with the utility end customers.

U.S. Business Model

Declines in subsidy markets in Europe only accentuated the importance of the U.S. market, largely ignored by First Solar until only recently. The market was far less developed than that of Europe and likely required catalyzing by First Solar or another player to grow. For this reason, the company had made a significant investment in Solar City on the residential side and had acquired Turner Renewable Energy and OptiSolar to acquire EPC and development capabilities, respectively; these were required to serve the growing utility-scale solar market.

While downstream integration in the U.S. appeared to be a good near-term strategic move for the company, it remained to be seen if this was where First Solar wanted to be in the long run. Was EPC simply a sales channel? As Lamon noted, "We're in the business of selling modules but business takes you places … as the market matures." Participation in the systems (Turner Renewable Energy, OptiSolar) business also presented a number of challenges for the company. Most superficially, the gross margins on systems were roughly 5-7 percent as compared with module margins north of 55 percent, leading to overall gross margin compression as this part of the business continued to grow.[55] Perhaps of more concern to actual business fundamentals was the fact that First Solar's participation in the EPC portion of the value chain brought the company into potential competition with its current customers—systems integrators, developers, and IPPs. A major challenge for the company going forward would be to find a balance between catalyzing U.S. utility-scale solar growth while maintaining relationships with current customers.

Technology Risk

As of 2010, First Solar seemed to have picked the leading technology platform for making photovoltaic modules. However, its future success in the industry was far from assured. With six sites, 24 production lines, and over 1GW of production capacity on a single technology, First Solar was making a huge bet on CdTe. With the company's significant experience curve

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[54] "About – Juwi Solar Inc.," Juwi Solar Inc., June 22, 2010, <http://www.juwisolar.com/about/>.

[55] First Solar Analyst/Investor Meeting Presentation, Las Vegas, June 24, 2009.

advantage over every other CdTe producer, First Solar certainly appeared to have no worries about the CdTe competition ever catching up. The critical question was whether the fundamental technology had enough runway to allow the company to continue to be the cost leader going forward.

A number of other technologies offered the potential to unseat First Solar. With a theoretical upper limit of more than 30 percent, c-Si solar cells could challenge CdTe if the cost of crystalline silicon were low enough. As silicon wafer supply finally caught up with the increased demand driven by the solar industry, c-Si prices plummeted in late 2009, bringing c-Si solar cells far closer to cost parity with CdTe. (See **Exhibit 12** for Silicon Price Trend from 2000 to 2009.) Despite most c-Si players having lower individual capacity than First Solar, the aggregate market was roughly 5x larger (see **Exhibit 11** for industry market shares), and nearly all the Chinese players were aggressively putting research dollars behind this technology, implying that further cost reductions could potentially occur. In addition to c-Si, CIGS cells produced by the National Renewable Energy Laboratory (NREL) had achieved a 19.9 percent conversion efficiency under optimal conditions, roughly 20 percent higher than the best CdTe cell.[56]

Despite First Solar's current technology leadership within the solar industry, the company was keenly aware of the potential for disruptions. Eaglesham remarked, "Technology is a moving target, so I'd frankly be surprised if CdTe were the last word…."

Eaglesham further explained how he thinks about disruptive technologies:

> It's hard for a company to survive major technology disruptions, and it's something that I spend a lot of my time thinking about. How do I position us as a company so that when the next major technology disruption comes around the bend I'm not caught like a deer in the headlights? And it's challenging, but I think you begin by accepting it as reality and saying it's going to happen; I think you really start by recognizing the problem, which is not the same thing as solving the problem … and then we try to stay focused on the long-term goals.

To mitigate the threat of disruption, Eaglesham ensured that his team was constantly evaluating technologies in the market for potential integration into First Solar. These technologies were all evaluated on the company's four key criteria (mentioned early in the case), in addition to a fifth consideration—that of maturity, as the company was hesitant to commit to significant development of early-stage innovations. In contrast to the technology portfolio approach taken by some in the industry such as QCells or REC, First Solar would likely only consider select investment in a technology that has real potential at scale. Eaglesham commented, "Some

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[56] "Record Makes Thin-Film Solar Cell Competitive with Silicon Efficiency," NREL press release, March 24, 2008.

companies had never met a technology they didn't like … so they bought a lot of stuff … and they took a lot of attention off of the core product."

In addition to scanning the external landscape for technology acquisitions, First Solar engaged in its own internal research and development of promising solar innovations. Furthermore, the recruitment of top talent from photovoltaic start-ups and research labs ensured that the company remained on the leading edge of technology.

Taking Solar Energy to Terawatt Scale

Global energy demand in 2008 was estimated by BP to be 474 exajoules or an average rate of 15 terawatts (TW).[57] The vast majority, roughly 75 percent, of generation was derived from fossil fuels (see **Exhibit 13** for global energy consumption details). Renewable sources comprised barely 2 percent of the world's total energy consumption. Furthermore, PV solar was merely a thin sliver—0.04 percent of this total number. Thus, while much of the discussion about the solar industry often focused on share gains and losses amongst PV players or amongst renewable energy players, the real opportunity was far larger than what was implied by the current size of either market. As Sohn remarked, "we're not competing against other PV companies ... we're competing against the entire electricity generation market."

To achieve this loftier goal of competing with broader generation, PV solar had to overcome certain fundamental issues that placed limitations on its more widespread use. The first issue was simply that of cost. Photovoltaic cost/watt was significantly higher than that for fossil sources and other renewables. Grid parity for a few high-cost applications might have been possible at this cost point, but broad adoption would require significant cost reductions. It remained unclear whether this would be possible with the current technology without a significant increase in fossil fuel prices.

A second fundamental issue, which had to be overcome with solar and a few other renewable sources such as wind power, was that of intermittency. With photovoltaics, energy was only generated while the sun shone on the device. Hence, they did not work at night, and often performed poorly in variable weather conditions. At their current level of penetration and limited application space, such performance was acceptable—utilities simply replaced peaker plant usage with photovoltaic energy while solar conditions were favorable and increased flex fossil plant usage when conditions were poor. At any meaningful level of penetration, however, this solution would not be pragmatic.[58] As Charles Fritts originally observed when he created the very first solar cell, some type of energy storage element would be needed for more widespread

[57] BP Statistical Review of World Energy 2009, June 2009.
[58] Interview with Bruce Sohn on June 4, 2010 suggested that roughly 7-10 percent of total load could be generated with renewables before intermittency becomes a significant problem.

adoption of solar. First Solar had also identified this technological gap, and was actively considering investments in many promising grid scale storage technologies.

A final challenge to broader use of solar energy was the lack of infrastructure to support less centralized generation. As large tracts of well insolated land were not necessarily within easy reach of the nearest transmission line, suitable sites for solar generation were somewhat limited in 2010. Thus, further development of the transmission infrastructure would likely be needed if solar penetration were to increase significantly. Moreover, where there was sufficient access to transmission and distribution infrastructure, in local municipalities for example, zoning and other permitting requirements made it difficult to tie into the grid for effective distributed generation. Here, a regulatory change such as Germany's feed-in-tariff could be needed to guarantee access to the grid for smaller, distributed generation projects. First Solar's role here was unclear, though the company's prior CEO, Mike Ahearn left his post in 2009 to pursue just these issues as a government liaison.

THE NEXT CHAPTER

As the mercury once again climbed above 110 degrees and he glanced out at the sun drenched city of Tempe, Sohn realized just how far First Solar had come in its short existence; from an unproven start-up with novel technology to the leader in solar module placements worldwide. However, he also realized just how far the company had yet to go. The challenges would be more difficult this time as the whole world would be watching what the company did now. Should the company try to expand aggressively into the U.S. and China to compensate for souring market conditions in Europe? Was downstream integration the appropriate way in which to catalyze the U.S. utility-scale market? Should the company invest in additional PV technologies? Sohn would have to ponder the answers to these questions while maintaining the company's tremendous growth trajectory—a challenge he looked forward to.

Exhibit 1
First Solar Executive Bios

Michael J. Ahearn, Executive Chairman of the Board

As of 2010, Michael J. Ahearn served as executive chairman of First Solar, after serving as CEO from August 2000 to September 2009. Prior to First Solar, he was partner and president of the equity investment firm JWMA (formerly True North Partners, L.L.C.), the majority stockholder of First Solar. Prior to joining JWMA, Ahearn practiced law as a partner in the firm of Gallagher & Kennedy.

Ahearn served on the boards of Arizona Technology Enterprises, Arizona State University Research Park, Homeward Bound, the Arizona Science Museum and later on the board of the German Marshall Fund of the United States. He received both a BA in Finance and a JD from Arizona State University.

Bruce Sohn, President

Bruce Sohn joined First Solar as president in February 2007. He was formerly a senior executive at Intel Corporation and had served on First Solar's board of directors since 2003. Prior to joining the management team, he was technical and managerial consultant to the company.

In 2010, Sohn was responsible for technology development, manufacturing, expansion, quality, EHS, supply chain, MIS and worldwide human resources. He was head of operations for First Solar's module business; systems engineering, procurement and construction business; and monitoring & maintenance business.

During his 24 years at Intel, Sohn played a leadership role in developing and manufacturing leading-edge semiconductor technology. He designed an early generation transistor and spearheaded initiatives in cycle time reduction and automated operations. He served as an integral part of the start-up team at five semiconductor fabrications plants, was program manager for Intel's conversion to 300mm wafers and managed Intel's two largest fabs. Sohn is an engineering graduate of the Massachusetts Institute of Technology.

Jens Meyerhoff, CFO and President Utility Systems Group

Jens Meyerhoff joined First Solar in May 2006 as chief financial officer. Prior to joining First Solar, Meyerhoff was the CFO of Virage Logic Corporation, a leader in embedded infrastructure intellectual property. Meyerhoff was employed by FormFactor, Inc., a manufacturer of advanced wafer probe cards, as chief operating officer from April 2004 to July 2005, senior vice president

of operations from January 2003 to April 2004 and chief financial officer from August 2000 to March 2005. Prior to joining FormFactor, Inc., from March 1998 to August 2000 Meyerhoff was CFO and senior vice president of Materials at Siliconix Incorporated, a manufacturer of power and analog semiconductor devices. Meyerhoff holds a German Wirtschaftsinformatiker degree, which is the equivalent of a Finance and Information Technology degree, from Daimler Benz's Executive Training Program.

TK Kallenbach, Executive Vice President, Marketing and Product Management

TK Kallenbach joined First Solar in December 2009, as EVP of marketing and product management. Prior to joining First Solar he was a senior executive at Honeywell where he led Aerospace strategic planning, product marketing, product management, mergers and acquisitions, and marketing communications. His organization created and drove Honeywell Aerospace strategy through product portfolio integration and product line management. Kallenbach began his career at Honeywell (formerly AlliedSignal) in 1979, where he held a variety of senior technical leadership positions, including vice president of engineering and technology for Aerospace Electronics, Defense & Space Electronic Systems, and Propulsion Engines and Systems; and senior business leadership positions, including vice president of business aviation, director of HTF7000 propulsion systems, and director of helicopter engines. He earned a bachelor of science degree in mechanical & aerospace engineering and a master of business administration from Arizona State University.

Jim Lamon, Senior Vice President of Systems Engineering and Construction

Jim Lamon came to First Solar in 2008 and led the company's efforts in engineering, procurement, construction and commissioning of new solar power plants in North America. He had more than 20 years of experience in the construction of power plants for major utility clients. He oversaw the rapid growth of operations at several major firms. Prior to joining First Solar, Lamon served for three years as president, fossil power for The Shaw Group, an engineering and construction firm based in Baton Rouge, Louisiana. He was responsible for client interface, execution, strategic planning and personnel development for all of the company's North American and international power EPC projects for clients including Duke Power, Dominion Power, PPL, PSEG and Xcel.

Prior to Shaw, Lamon spent seven years as the president, Power Division—North America at Aker Kvaerner, a provider of engineering and construction services. He successfully negotiated multiple EPC contracts with no missed schedules and no disputes for clients such as Archer Daniel Midland, Weyerhauser and Georgia Pacific. Prior to Aker Kvaerner, he spent six years in the United States Army Corp of Engineers, exiting at the rank of Captain.

Lisa Krueger, Vice President, Sustainable Development, First Solar

Lisa Krueger joined First Solar in June, 2006 and subsequently served as vice president of sustainable development. In this role Krueger led First Solar's product life cycle management approach and global efforts on ensuring that the environmental attributes of PV are understood and valued from a technical, public policy, and customer perspective. Under Krueger's leadership, First Solar implemented its vision of creating a pre-funded collection and recycling program for its modules. She actively worked on the development and implementation of PV CYCLE, the European industry association focused on the development and implementation of a voluntary industry-wide module take-back and recycling program, and has supported numerous studies on the environmental aspects of PV, many involving life-cycle assessment. She was also the chair of the Solar Energy Industries Association (SEIA) Environmental, Health & Safety Committee. Krueger received her MBA from Rice University, and holds an undergraduate degree in Chemical Engineering from the Missouri University of Science and Technology.

Source: First Solar.

Exhibit 2
Levelized Cost of Electricity Generating Technologies

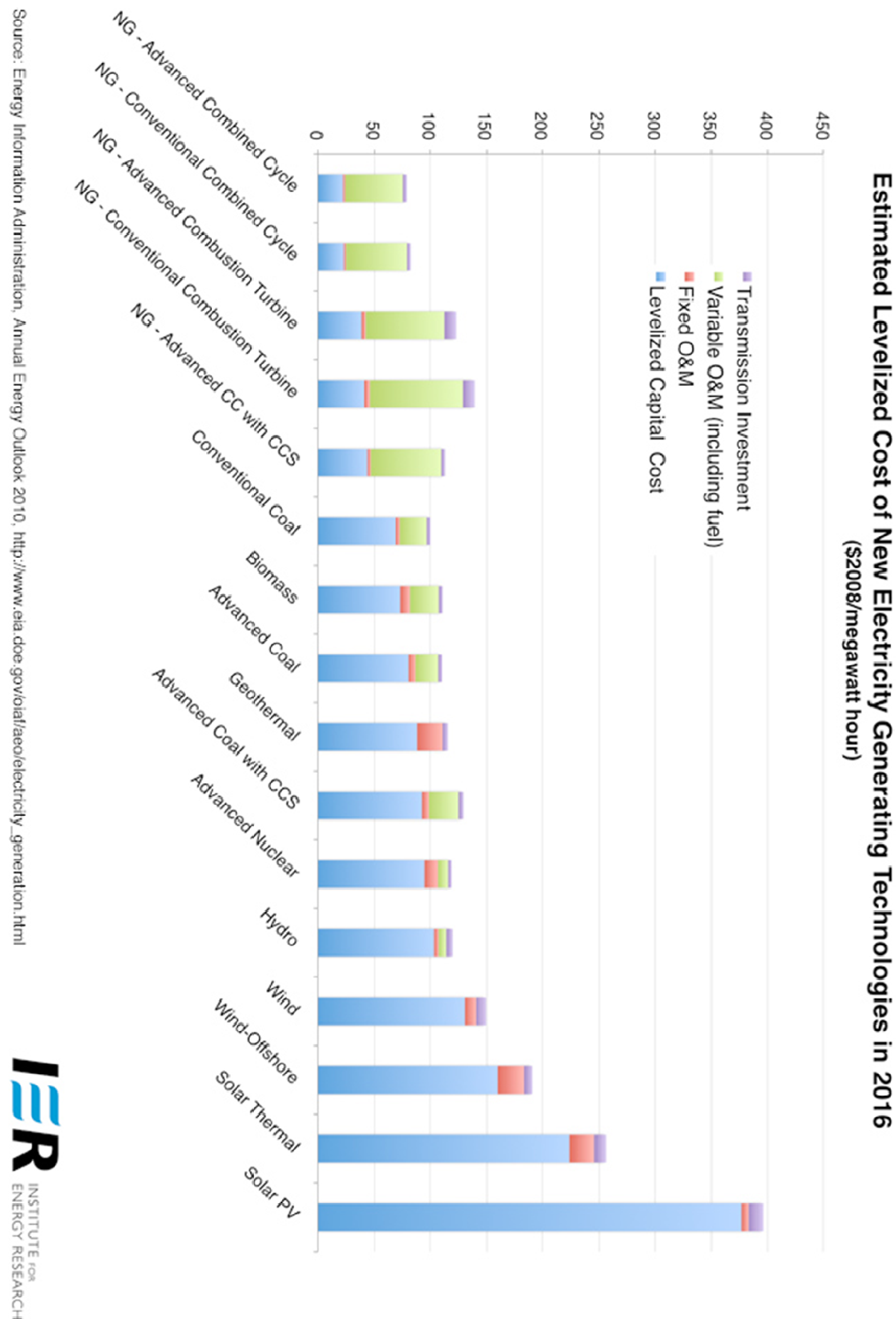
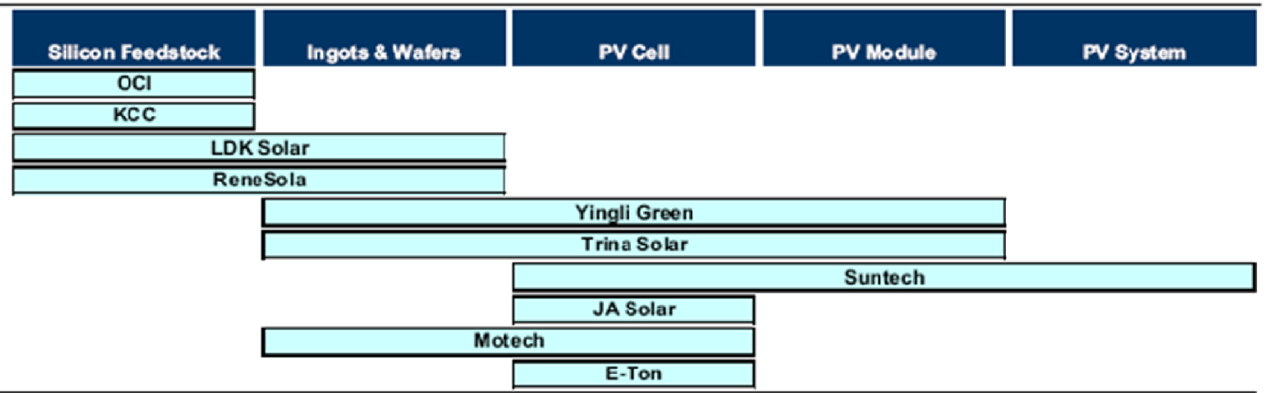


Exhibit 3
Solar Value Chain

Morgan Stanley

MORGAN STANLEY RESEARCH
July 20, 2009
Solar Industry

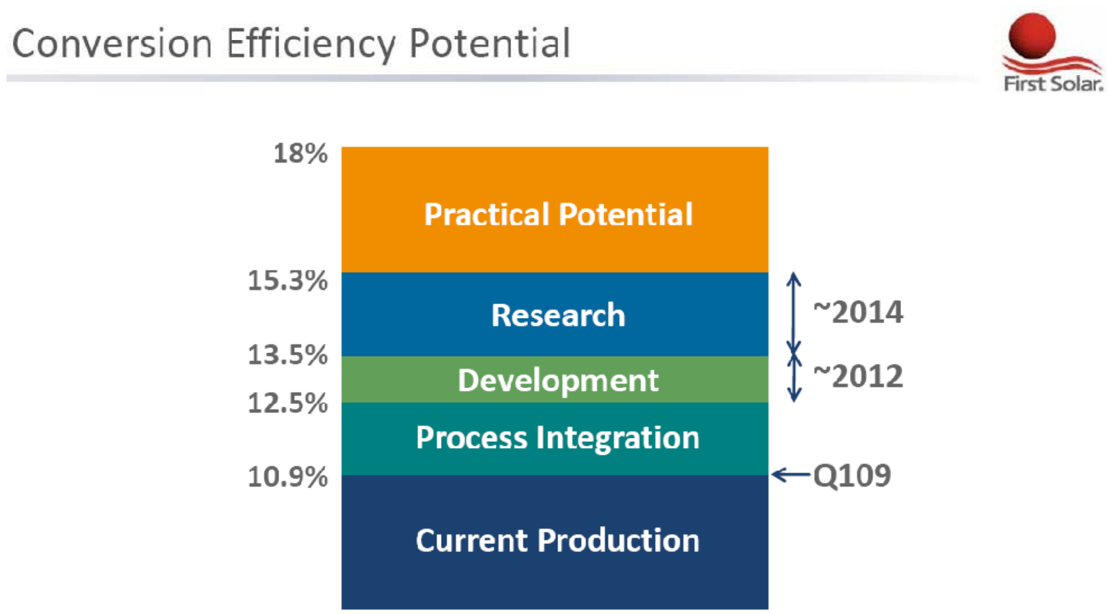
Issue #2: Upstream or Downstream?



	Silicon Feedstock	Ingots & Wafers	PV Cell	PV Module	PV System
Pricing Leverage	High - Relatively fixed cost, but high selling price.	Moderate - Primarily an agency processing Biz with high margin risk.	Low - Primarily an agency processing Biz with low margin risk.	Low - Primarily an agency processing Biz with low margin risk.	Very low.
Operating Leverage	High - Depreciation and other sticky costs are 25% of COGS.	Moderate - Depreciation and other sticky costs are 20% of COGS	Low - Depreciation and sticky costs are 12% of COGS.	Very Low - Depreciation and sticky costs are 5% of COGS.	Very low.
Supply Chain Risk	No risk on raw materials, risk of enforcing sales contracts.	Moderate risk of raw material contracts, but high risk of sales contracts.	Very high risk of managing supply contracts as well as sales contracts.	High risk of managing sales contracts.	High risk of project management delays
Industry Structure	Oligopoly, which is beginning to fragment.	Oligopoly, which is beginning to fragment.	Highly Fragmented. May see consolidation.	Highly Fragmented. May see consolidation.	Highly fragmented, difficult to scale
Entry Barrier	High due to long learning curve to achieve the desired cost structure.	Moderate for technology/process, but rising due to need for capital to achieve scale and attractive cost structure.	Limited entry barriers until high efficiency cells become mainstream.	No entry barriers.	No entry barriers other that capital.
Room for Differentiation	High level of differentiation depending on "chemical knowledge"	Moderate level of differentiation based on cost.	Currently low differentiation. Possible from high efficiency cells	Limited scope.	Limited scope
Capacity Lead Time	Very High - 18 months	Moderate - 6 months	Low - 3 months	Very Low - 1 month	Very low

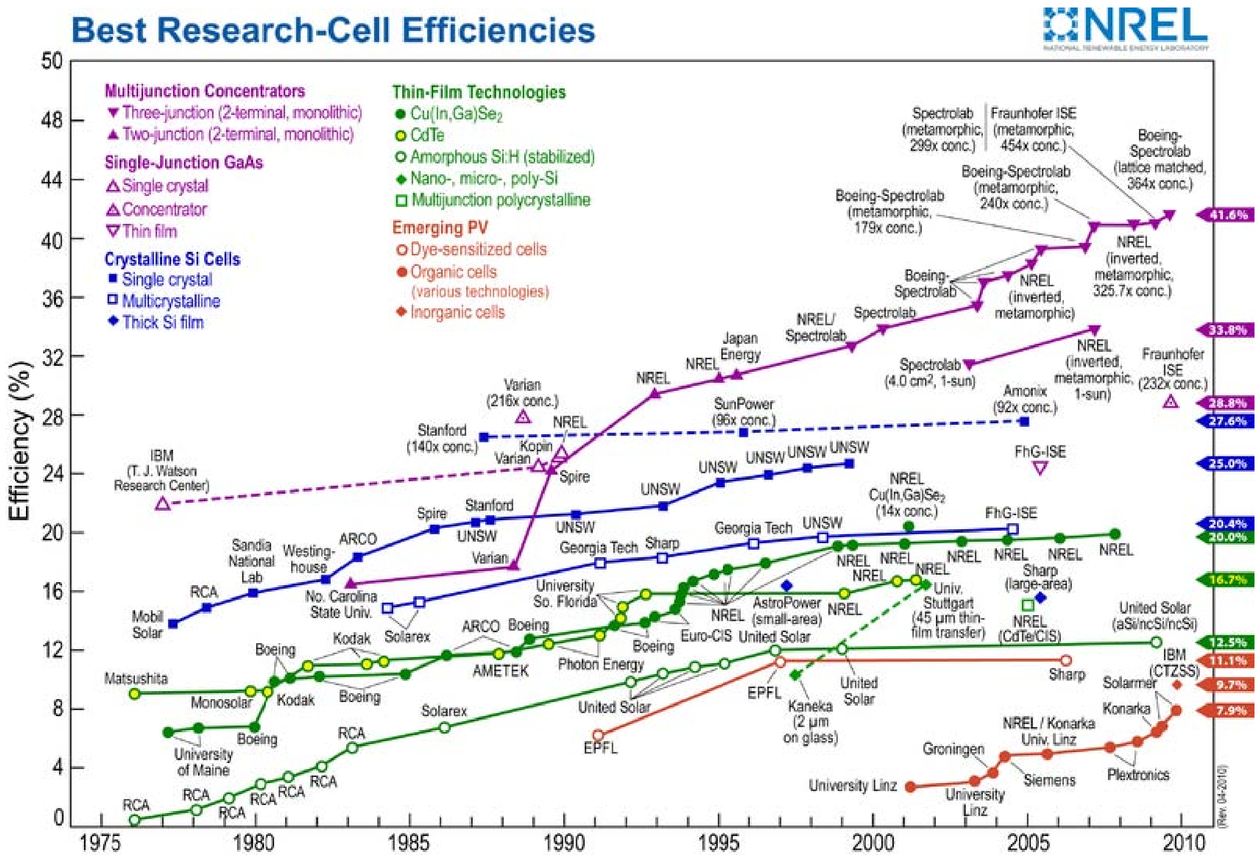
Source: Morgan Stanley Research

Exhibit 4
Improvement Roadmap for First Solar CdTe Cell



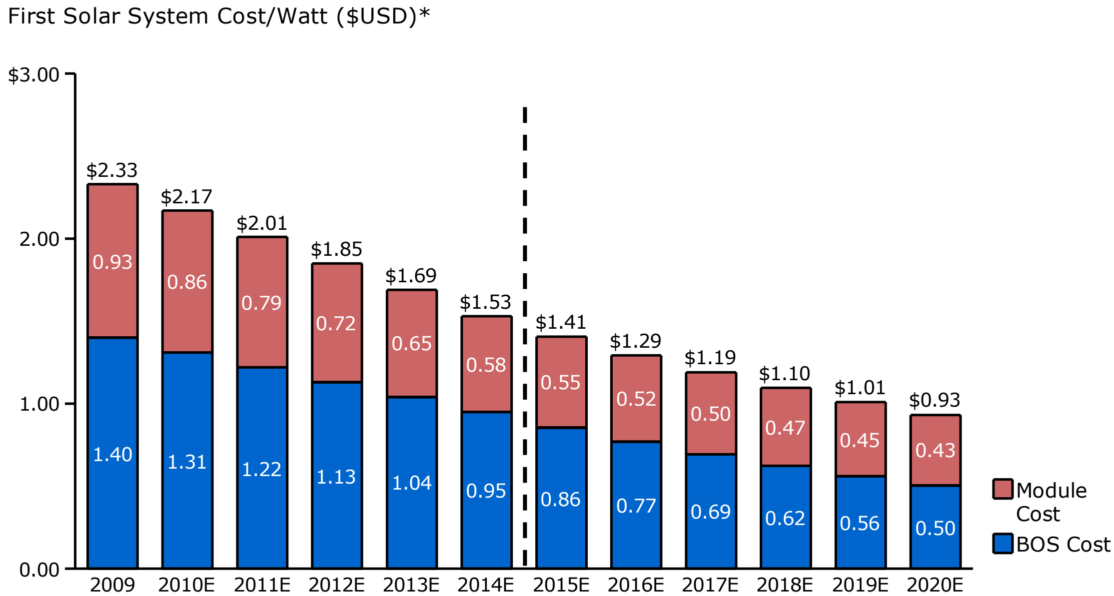
Source: First Solar.

Exhibit 5
Efficiencies of Current PV Technologies



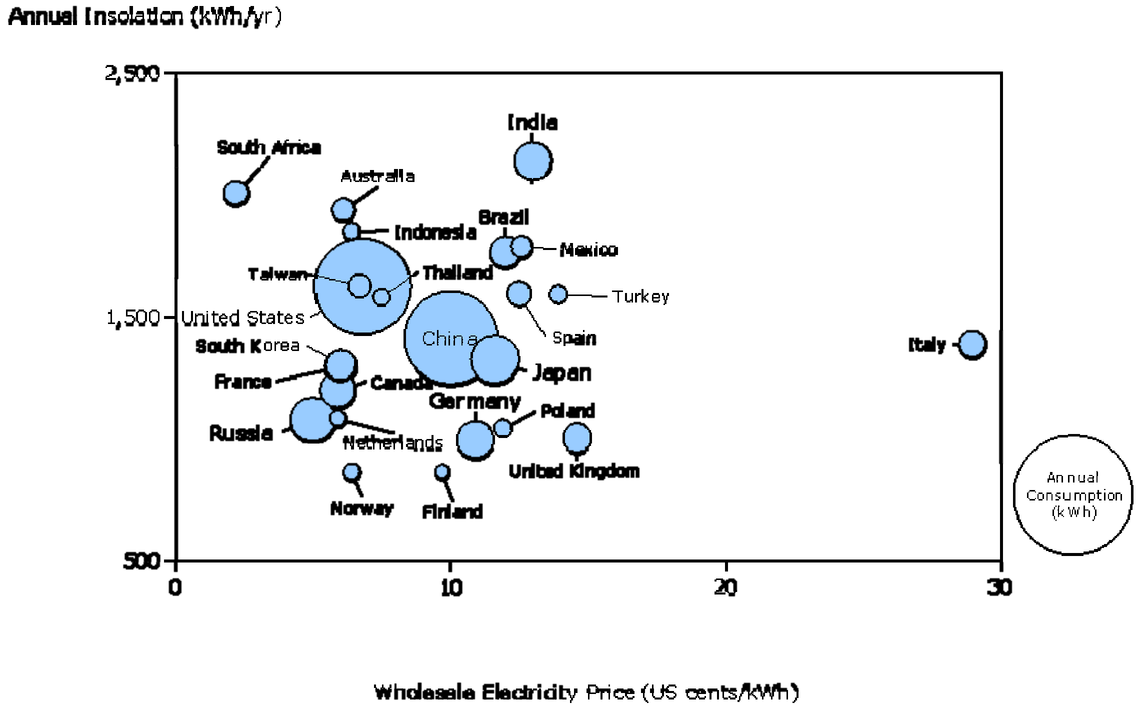
Source: National Renewable Energy Laboratory (NREL).

Exhibit 6
System Cost per Watt Trend



*Adapted from First Solar Analyst/Investor Presentation June 24, 2009. Company only provided guidance through 2014E. Additional projections assume 5% and 10% declines in module and BOS costs, respectively.
Source: First Solar.

Exhibit 7
Worldwide Electricity Prices vs. Annual Insolation



Source: Insolation data from NASA, wholesale prices from EIA.

Exhibit 8
First Solar Financial Performance (Income Statement & Balance Sheet)

Income Statement					
$US MM, in '000s	**2007**	**2008**	**2009**	**2010E**	**2011E**
Total Revenue	504	1,246	2,066	2,796	3,945
Cost of Goods	253	568	1,022	1,739	2,550
Gross Profit	251	678	1,045	1,057	1,395
Gross Margin	*50%*	*54%*	*51%*	*38%*	*35%*
Research and Development	15	34	78	94	106
% of sales	*3%*	*3%*	*4%*	*3%*	*3%*
SG&A	82	174	273	317	380
% of sales	*16%*	*14%*	*13%*	*11%*	*10%*
Production Startup Costs	17	33	14	24	35
% of sales	*3%*	*3%*	*1%*	*1%*	*1%*
Total Operating Expenses	114	240	365	435	521
Operating Income	137	438	680	622	874
Operating Margin	*27%*	*35%*	*33%*	*22%*	*22%*
FX Gain/Loss	2	6	5	-	-
Interest Income	20	21	10	16	23
Interest Expense	(2)	(1)	(5)	(3)	(2)
Other Income	(1)	(1)	(3)	(1)	(1)
Total Other Income	19	26	7	12	20
Pre-tax Income	156	464	686	635	894
Pre-tax Margin	*31%*	*37%*	*33%*	*23%*	*23%*
Taxes (benefit)	(2)	115	46	75	132
Tax Rate	*-2%*	*25%*	*7%*	*12%*	*15%*
Net Income (loss)	158	349	640	559	762
Net Margin	*31%*	*28%*	*31%*	*20%*	*19%*

Balance Sheet			
December Year-End	**2007**	**2008**	**2009**
Cash and Investments	637	792	785
Accounts Receivable	18	62	227
Inventories	40	122	153
Other Assets	107	102	187
Total Current Assets	803	1,078	1,351
Net PP&E	430	843	989
Project Assets			131
Marketable Securities		30	330
Restricted Cash		30	37
Inventories		-	22
Other Non-current Assets	139	135	490
Total Long-Lived Assets	569	1,037	1,998
Total Assets	1,371	2,115	3,349
Notes Payable & Curr LTD	132	146	37
Accounts Payable	25	176	262
Other Current Liabilities	30	60	95
Total Current Liabilities	187	382	395
Long Term Debt	69	164	146
Other Non-current Liabilitie	19	56	155
Total Liabilities	274	602	697
Total Stockholders' Equity	1,097	1,513	2,652
Total Liabilities and Equity	1,371	2,115	3,349

Exhibit 8 (continued)
First Solar Financial Performance (Segment Information)

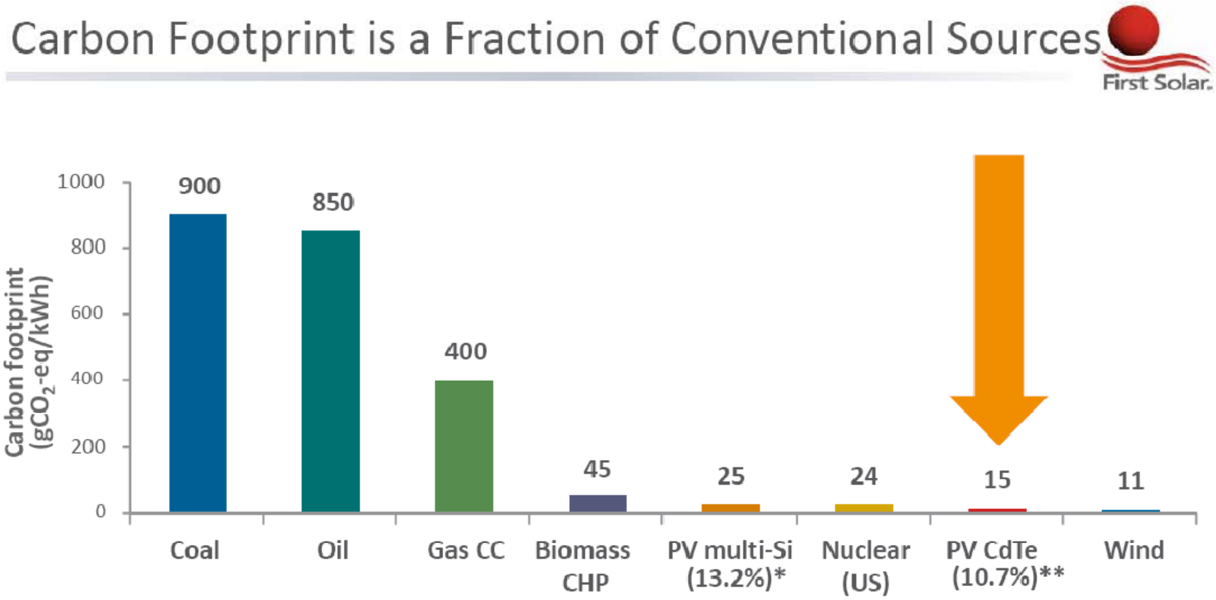
Net Sales ($US MM)	2010 E	% of Sales	2009	% of Sales
Modules	2,100	75%	1,951	94%
EPC/Development	700	25%	115	6%
Total	2,800	100%	2,066	100%

Net Sales ($US MM)	2009	% of Sales
Germany	1,334	65%
France	249	12%
US	137	7%
RoW	346	17%
Total	2,066	100%

First Solar Financial Performance (Stock Price)

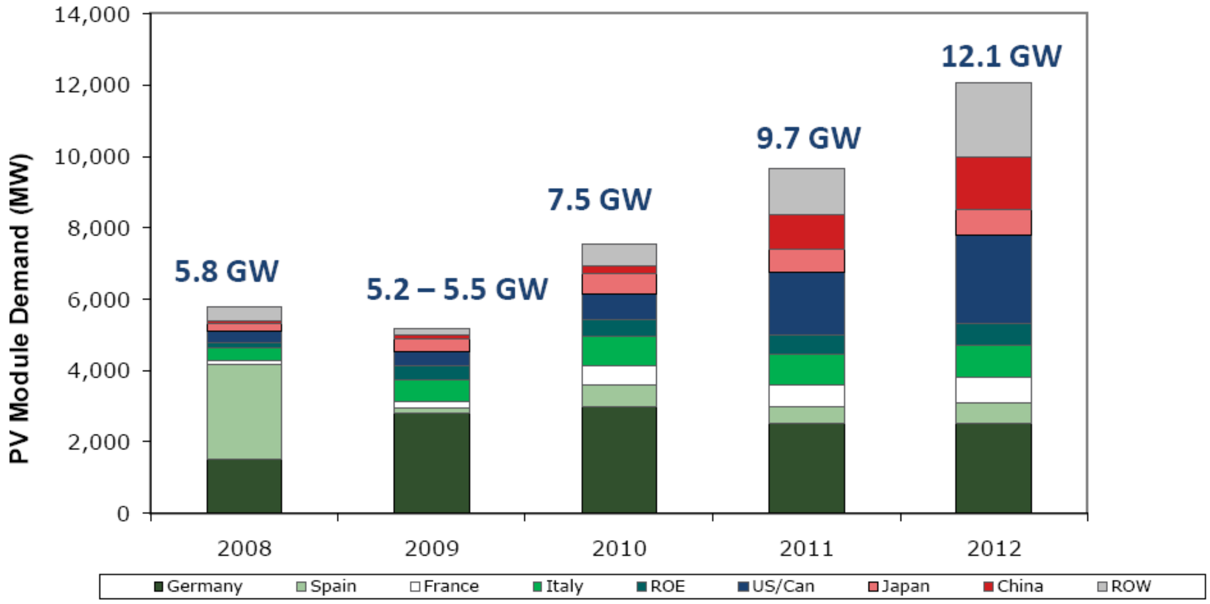
Source: First Solar.

Exhibit 9
CO_2 Footprint Analysis of Generation Technologies



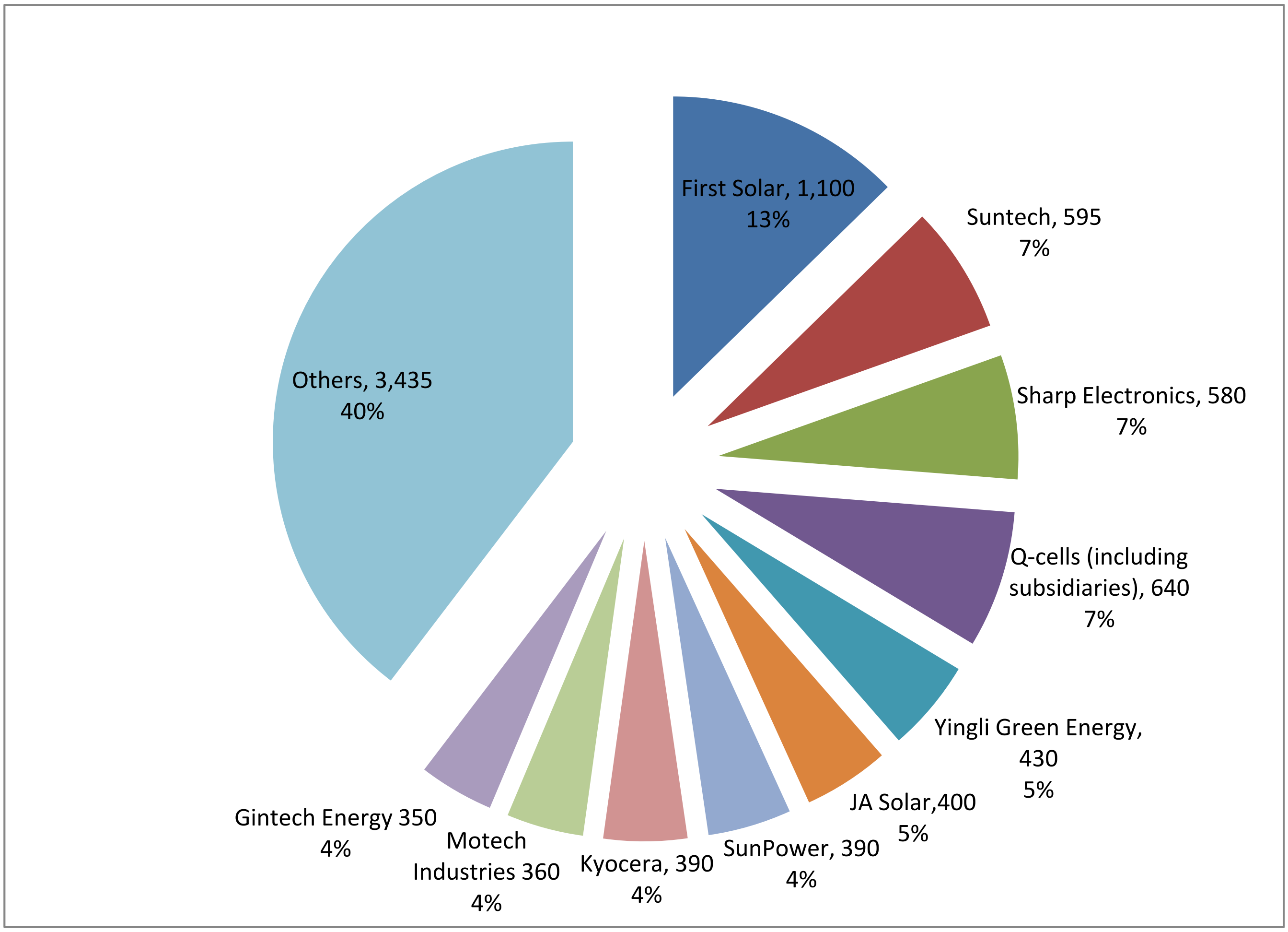
Sources: *de Wild-Scholten, M., presented at CrystalClear Final Event in Munich on May 26, 2009. **de Wild-Scholten, M., 'Solar as an environmental product: Thin-film modules – production processes and their environmental assessment,' presented at the Thin Film Industry Forum, Berlin, April, 2009. Both PV technologies use insolation of 1700 kWh/m². All other data from ExternE project, 2003; Kim and Dale, 2005; Fthenakis and Kim, 2006: Fthenakis and Alsema, 2006; Fthenakis and Kim, in press.

Exhibit 10
Solar Industry Demand



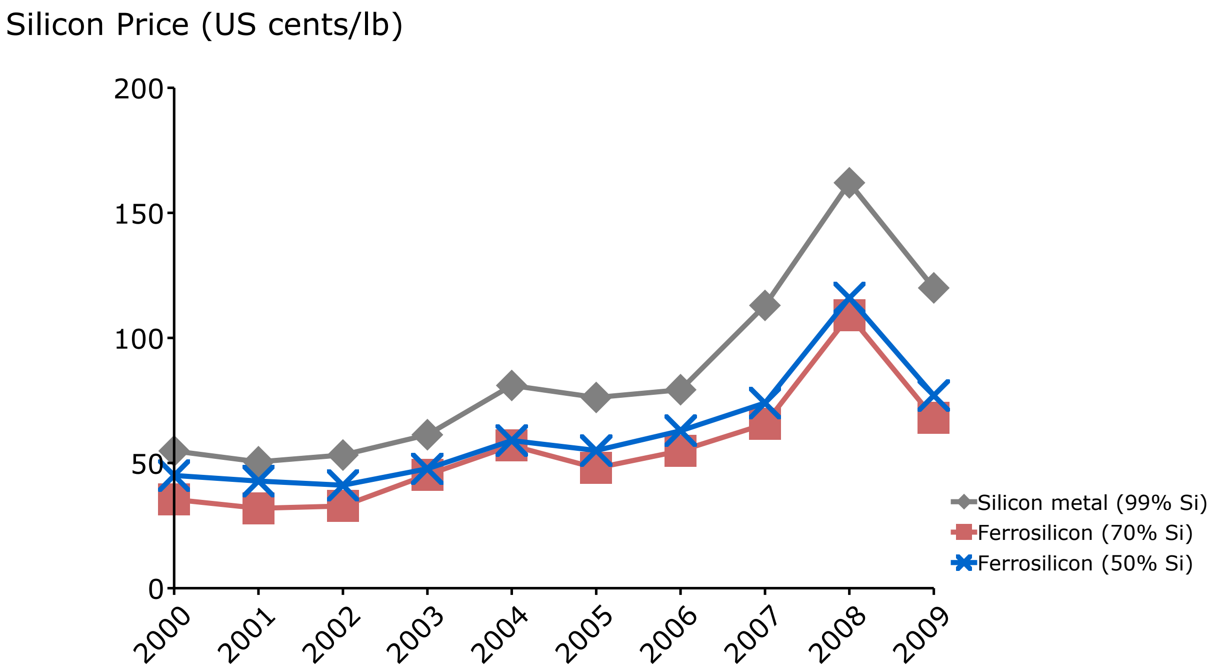
Source: First Solar investor presentation.

Exhibit 11
Solar Industry (Production MW) and Market Share (%) 2009
(Forecast September 2009)



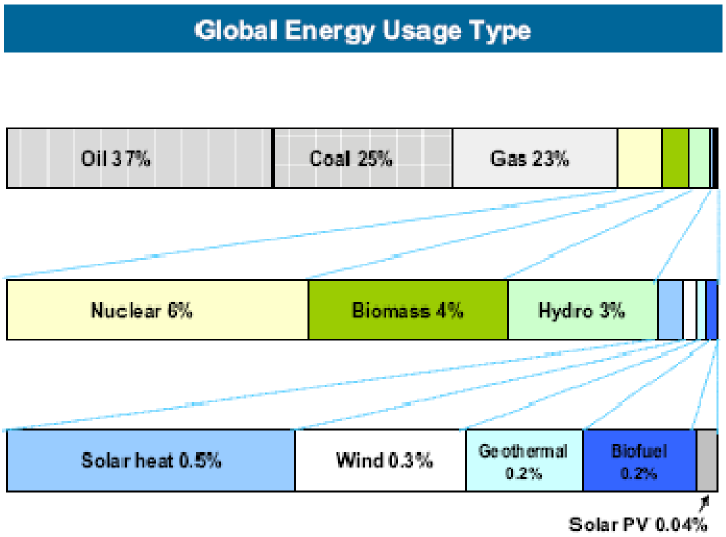
Source: iSuppli.

Exhibit 12
Silicon Price Trend 2000-2009



Source: USGS.

Exhibit 13
Global Energy Consumption by Source 2008



Appendix 1

Glossary of Terms

Balance of System (BOS)—Components and costs associated with a solar system separate from the module. These include development, engineering, permitting, construction, mechanical support structures, wiring and cabling, batteries, power conditioning circuits, inverters and all installation labor.

Band Gap—Difference between bound state (valence band) and free state (conduction band) within a semiconductor material. Energy necessary to knock an electron into the conduction band.

Binary Compound—A compound that consists of two elements in a 1:1 ratio; one atom of element A and one atom of element B.

Cadmium Telluride (CdTe)—A binary compound of Cadmium and Tellurium used as the light absorbing layer in First Solar cells.

Copper Indium Gallium (Di)selenide (CIGS)—Refers to a family of chemistries of the form $CuIn_xGa_{(1-x)}Se_2$ that may be used as light absorbing layers in thin film cells. Currently CIGS cells boast higher conversion efficiencies than CdTe cells.

Carbon Footprint—A measure (in tons of CO2) of how much Carbon Dioxide gas was produced as a result of fabricating a solar module.

Charge Carrier—A charged particle capable of conducting electricity. Usually an electron or positively charged ion.

Conversion Efficiency—The percentage of solar energy supplied to the cell that is successfully converted into electrical energy.

DC to AC Conversion—The process of converting continuous (time invariant) direct current (DC) that is produced by solar cells into time varying alternating current (AC) that is used by the world's transmission and distribution grid.

Diode—An electronic component that acts as a one-way valve by restricting the flow of current to a single direction. Crude solar cells are fabricated in much the same way as semiconductor diodes, which led to their discovery by Bell Labs.

Distributed Generation—The generation of electricity at the point of consumption. This is contrary to conventional generation, which is concentrated and must be transmitted and distributed to the load.

Doping—Process by which impurities are added to silicon (or some other semiconductor) to create either positive (p-type) or negative (n-type) charge carriers in the material.

Electrical Load—Refers to the circuit connected to the electrical grid. Thus all houses, factories, public lights and other power consuming entities would represent the load on the grid.

Electrode—An electrical conductor used to make contact with a nonmetallic part of a circuit (such as the semiconductor light absorbing layer of a solar cell).

Energy Payback Time (EPBT)—Measure of the time required for device to produce sufficient energy to offset that used in its production.
Engineering Permitting and Construction (EPC)—Site design, permit acquisition and site construction activities. Permit acquisition includes obtaining approval to use land for solar generation purposes, obtaining rights to access transmission infrastructure and clearing other legal hurdles required to make site suitable for electricity generation. EPC also more broadly refers to the module sales channel created when First Solar performs EPC activities.
Epitaxial Matching—Process of growing a perfectly matched layer atom by atom on top of a monocrystalline silicon wafer. This type of processing is far more time consuming and expensive than vapor deposition techniques.
Erneuerbare-Energien-Gesetz (EEG)—Translates roughly into "Renewable Energy Sources Act," and is the law governing Germany's feed-in tariff.
Exajoule—A unit of energy equivalent to 10^{18} Joules.
Feed-in Tariff (FiT)—Government incentive in which power suppliers are guaranteed a subsidized price for their power and access to the grid. Yearly degressions reduce the price received to encourage cost improvements.
Grain Boundary—Interface between two or more discrete crystals in a polycrystalline material. There are many of these in poorly ordered materials. Grain boundaries diminish conductivity of the material.
Independent Power Producer (IPP)—An independent organization that contracts with a utility to provide a specified amount of power at a particular rate, usually via a PPA agreement.
Insolation—A measure of the solar resource in a particular region. Measured in Watts/sq. meter.
Joule—The SI unit of measure for energy. Equivalent to the work required to continuously produce one watt of power for one second. Units may be expressed as watt*seconds (W*s).
Kilowatt-Hour—A measure of energy used in the utilities industry. Equal to 1000Watts*3600seconds or 3.6 Megajoules.
Levelized Cost of Electricity (LCOE)—Refers to the fully amortized cost of producing a unit of electricity, accounting for the solar resource, system cost/watt, module lifetime, operating and maintenance costs, capital subsidies and other parameters that affect overall cost. Yields an average $/kwh figure that may be compared across generation technologies.
Life Cycle Analysis (LCA)—Analysis of all environmental and energy impacts associated with the production of a solar cell. Includes material inputs, processing, use, disposal and recycling associated with the device.
Megawatt—A unit of power equal to 10^6 Watts.
Monocrystalline Silicon (c-Si)—A perfect single crystal of silicon.
Polycrystalline Silicon—A collection of many silicon crystals. This form is of lower quality than monocrystalline Si and exhibits poorer conductivity as a result.
Amorphous Silicon (a-Si)—Non-crystalline form of silicon. The lowest quality form of silicon, which exhibits even poorer electrical characteristics than polycrystalline Si, but is far cheaper to produce.

PN Junction—Interface created when p-type (slightly positively doped) silicon is placed in contact with n-type silicon. The junction produces a built-in electric field, which may be used to separate charge carriers.
Power Purchase Agreement (PPA)—Agreement between utility and IPP that specifies the amount of power to be supplied, over what term and at what price.
Recombination—Process by which a free electron gives up its energy and returns from the free state to the bound state within a material.
Selenium—Atomic element number 34. Selenium is a non-metal, similar to Tellurium and Sulfur. It is one of the key components of the CIGS solar cell.
Solar Cell—The fundamental light converting element within a solar module. Directly converts light into electricity.
Solar Module—A collection of solar cells bundled together to increase voltage and current produced. The cells are also encapsulated in durable, weather-resistant packaging.
Sublime—To convert directly from solid to vapor.
Terawatt—A unit of power equal to 10^{12} Watts.
Vapor Deposition—Processing technique in which material is vaporized (turned into a gas) and then deposited onto a surface. Very fast deposition rates are possible with this technique.
Volt/Voltage—The SI unit of electromotive force. Also referred to as the electronic potential difference.
Watt—Scientific unit of power or rate of energy transfer. Equal to energy transfer of one joule/second.
Weighted Average Cost of Capital (WACC)—The rate of return expected by all the company's security holders (stockholders and debt holders) on the company's assets.